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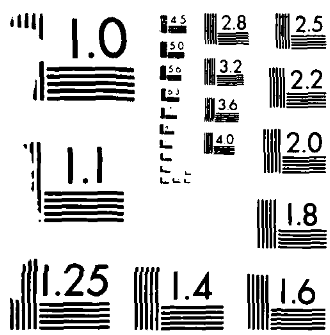

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INTERACTIONS MEASUREMENT PAYLOAD FOR SHUTTLE (IMPS) DEFINITION PHASE STUDY FINAL REPORT

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15 December 1984

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The Interactions Measurement Payload for Shuttle (IMPS) project will study interactions between large space vehicles, such as the shuttle, and the low altitude plasma environment over the polar caps and in the auroral zone. Studies will be conducted from the orbiter bay and from a shuttle-based subsatellite, several investigations, and an environmental monitoring package. This will be the first of a series of missions to begin in 1987. The Definition Phase Study Final Report presents the objectives and requirements of the IMPS project and instrument system followed by the mission design they dictate. The bulk of the report is a technical discussion of the investigations and work done on the space and instrument systems, describing both their capabilities and limitations. A description of the steps for reliability/quality assurance is followed by the recommendations of the JPL engineers and scientists involved in this phase of the IMPS project.

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INTERACTIONS MEASUREMENT PAYLOAD FOR SHUTTLE (IMPS)

DEFINITION PHASE STUDY

FINAL REPORT

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CONTENTS

SECTION 1

INTRODUCTION

This final report summarizes the efforts undertaken by the Jet Propulsion Laboratory in defining a project designated as Interactions Measurement Payload for Shuttle (IMPS). The work performed has been sponsored by the Air Force Geophysics Laboratory (AFGL), as part of Air Force Program Element 63410F.

IMPS is planned as a shuttle-compatible, integrated instrument system capable of defining spacecraft interactions in the auroral/polar environments, while obtaining engineering design data for use by the Air Force in future space programs. The work at JPL has concentrated on the engineering/ science aspects of the mission, on mission design considerations, and on understanding the instrument payload interactions with, and impact on, the shuttle itself as well as a possible free-flyer spacecraft. The IMPS Project anticipates multiple IMPS missions.

The early part of the JPL work was directed at two key aspects of the candidate mission:

1) Gathering Air Force science and engineering requirements for auroral/polar-related data

2) Defining a candidate mission and the payload with which to gather this data.

Toward the end of this definition phase, specific investigations were selected by AFGL, from which JPL developed cost/implementation information for the candidate instruments.

One of the major activities in the past year focused on identifying the measurements to be made by the Interactions Measurement Payload for Shuttle (IMPS) in order to meet the objectives defined by AFGL. These

objectives, based on Air Force mission requirements, are concerned with space-environment induced interactions and their effect on the operations of the following onboard systems:

1) Operation of cooled, multi-element infrared detection systems in the polar/auroral environment.
2) Operation of space-based radar systems in the polar/auroral environment.
3) Operation of space-based laser systems in the polar/auroral environment.
4) Space systems deployment or on-orbit repair, necessitating Extra Vehicular Activity (EVA) by military astronaut in the polar/auroral environment.

Studies of the polar/auroral environment were initiated by JPL in the course of this project effort. From these studies, JPL has been developing a data base of anticipated induced environments and the resultant environmental interactions. This data base will be expanded during succeeding years to provide the IMPS investigators with background modeling information to be used in preparing for this participation in the IMPS flight program.

JPL helped organize an Engineering/Science Working Group (ESWG) for the purpose of formulating and submitting measurement recommendations to the AFGL. The ESWG was composed of engineers and scientists with expertise in space systems technologies. The ESWG also included representatives from universities, industry, and the government who participated in a year long study. The recommendations incorporated in the ESWG study were subsequently published by JPL.

In addition to the engineering/science-related work, JPL created a System Design Team (SDT) to evaluate the IMPS instrument system and its impact on the Shuttle. The team studied the various types of mechanical and electronic integration of the IMPS instruments into the Shuttle and selected standardized mechanical, electronic, and operational interfaces designed to optimize the many different types of measurements required on the various IMPS missions.

The concluding major project effort involved an assessment of the implementation capabilities of the candidate instruments supporting each of the selected investigations for the IMPS-1 flight. Each participating organization was contacted for requirements input. The weight, power requirements, and configuration of each instrument was determined as critically as possible, considering the early state of project definition. JPL then compiled a cost estimate for each one of the IMPS instruments and transmitted these results to AFGL. The final payload selection will be made by AFGL, once this final segment of information is available.

This report organizes the information generated as a result of accomplishing the preceding major IMPS activities. In view of the dynamic nature of this project, the efforts summarized in this document reflect initial conditions; the results therefrom must be viewed as preliminary in nature. This document, along with an earlier one entitled "Engineering/Science Payload Recommendations" (JPL Publication 84-56), is expected to provide an excellent basis for the development of a specific, comprehensive plan for the implementation phase of the IMPS project.

SECTION 2

OBJECTIVES AND REQUIREMENTS

2.1 PROJECT DEFINITION

During the definition phase of the IMPS, a set of project objectives and requirements was developed to form a foundation from which design decisions could be made. The project requirements were identified from the project objectives. The relationship between objectives and requirements is shown in Table 2-1. The project objectives are listed along the vertical axis; the derived project requirements appear along the horizontal axis. An X in the appropriate square indicates which project requirement supports which project objective. The table shows that each objective exacts multiple requirements, and each requirement meets several objectives.

2.1.1 Project Objectives

Project objectives for the IMPS were developed from the IMPS engineering/science objectives, documented experience of other flight programs, and input from early users of the Shuttle. These objectives will be reassessed at the outset of the implementation phase of the IMPS project.

Mission Success:

The engineering/science objectives of the IMPS mission are intended to characterize the environmental effects on space systems at Shuttle altitudes in the Earth's auroral regions. The results of the mission will be used to establish techniques for designing future Air Force space systems intended to operate in this environment. A comprehensive data base on spacecraft interactions will be compiled from IMPS mission results. Ultimately, the data will be incorporated into military standards and design guidelines. Specific Air Force systems and space operations that could be addressed by IMPS realized objectives:

TABLE 1. IMPS DEFINITION PHASE PROJECT REQUIREMENTS AND OBJECTIVES

OBJECTIVES	REQUIREMENTS: MINIMIZE INSTRUMENT INTEGRATION TEST TIME	DESIGN FOR RELIABILITY	INCORPORATE EASILY ON TO SHUTTLE	STANDARDIZE INSTRUMENT INTERFACES	ADAPT TO CHANGES IN THE OPERATING ENVIRONMENT	SIMPLIFY ENGINEERING/SCIENCE DATA DISTRIBUTION	UTILIZE EXISTING FLIGHT-PROVEN HARDWARE TO THE MAXIMUM EXTENT POSSIBLE	MAXIMIZE USE OF EXISTING SOFTWARE PACKAGES
MISSION SUCCESS		X			X		X	X
COST EFFECTIVENESS	X		X	X		X	X	X
MISSION FLEXIBILITY			X	X	X			
USER FRIENDLINESS				X		X		
SHUTTLE SORTIE/ SUBSATELLITE		X			X	X		
EARLY LAUNCH	X		X	X			X	X
MULTIPLE FLIGHTS	X	X	X	X		X		X

1) Cooled infrared detection systems
2) Space-based radars
3) Space-based lasers
4) Astronaut extra vehicular activities

Mission success will have been accomplished when specified engineering/science objectives are met.

Cost Effectiveness:

Design decisions shall fulfill the criteria for mission success at the lowest cost possible and within the established funding profiles.

Mission Flexibility:

Mission flexibility implies the adaptability of the configured IMPS to various Space Transportation System (STS) missions. This goal strives to minimize the impact that the IMPS will have on the Shuttle, as well as the impact other payloads will have on the IMPS. The IMPS design shall easily adapt to reasonable changes in the IMPS payload complement. Such changes can be accommodated within short time periods relative to the overall project schedule.

User Friendliness:

As instrumentation evolved from dedicated flights on expendable rockets, balloons, and spacecraft to the multi-payload manned shuttle environment, new benefits and complexities have been presented to the user. The IMPS system, as a goal, shall have a single payload-like flight environment while utilizing the resources, reusability, and manned capability provided by the Shuttle.

Shuttle Sortie/Subsatellite:

The IMPS flight system shall provide for three operational modes:

1) Shuttle sortie only (i.e., attached payload)

2) Subsatellite only (i.e., detached payload)

3) Shuttle sortie and subsatellite (i.e., both attached and detached payload).

Early Launch:

The first flight of the IMPS is planned for fiscal year 1988 from Vandenberg Air Force Base (VAFB). However, no design decision shall preclude accelerating the implementation schedule to meet an April, 1986 launch.*

Multiple Flights:

IMPS flight system shall be designed for a minimum lifetime of four Shuttle flights. It shall be designed for rapid turnaround and reflight.

2.1.2 Project Requirements

During the definition phase, project requirements have been used as design guidelines and constraints; they are described below. During the implementation phase, these requirements will be translated into implementation design requirements.

Minimize Instrument Integration Time:

The instrument development cycle is the frame from instrument authorization to the launch date. The time to integrate the instrument with the spacecraft is a separate time frame, but is included in the development cycle. In order to allow ample time for developing new instruments, the integration phase must be kept to a minimum. Basic incompatibilities not discovered until the instrument integration phase has started will result in

*During the definition phase, an April, 1986 launch date was baselined for two months (April and May). This requirement will be deleted for the implementation phase.

instrument cost overruns and costly schedule delays. Therefore, an instrument integration strategy shall be designed that identifies incompatibilities early in the instrument development cycle and allows for final instrument integration as late in the program as possible.

Another important aspect of the IMPS integration activity is to collect a set of prelaunch baseline test data that fully characterize and validate IMPS system performance. The instrument integration strategy shall include such a test plan.

Design for Reliability:

To insure mission success, reliability must be designed into the IMPS system from the beginning. Three specific steps shall be undertaken to achieve this end:

R&QA Manager

A reliability and quality assurance (R&QA) manager shall be assigned to the IMPS project during the definition phase and shall serve throughout the project.

Margins

Ample design margins shall be provided to achieve reliability criteria and avoid conflicts as the development schedule progresses. Margins shall be provided for power, number of switched power circuits, number of pyrotechnic events (if required), number of mechanical or electro-mechanical actuators, mass, length in shuttle bay, data system throughput, computing capability, memory capacity, and environment. The system engineer shall be responsible for maintaining the margin tables and shall control their application.

Risk Classification

The IMPS payload uses two quality, reliability, test, and analysis classifications. The engineering subsystems shall be class B which are critical to the system's functional operation and have direct interface with the Shuttle. The engineering/science instruments shall be class C, consistent with Shuttle safety requirements. Final determination of engineering subsystems and instruments classification shall be made within the first six months of the start of the project.

The following definitions for class B and class C classifications are excerpted from the NASA Management Instruction 8010 and JPL's payload classification standards.

Class B:

Payloads for which an approach characterized by compromise between minimum risk and minimum cost is appropriate because of the capability to recover from in-flight failure by some means that are marginally acceptable, even though it involves significantly high cost and/or highly undesirable intangible factors.

Class C:

Payloads for which reflight or repeat flight is planned in the event of soft failure or for which reflight or repeat flight costs are low enough to justify limited qualification and acceptance testing to end-item environmental screening.

Incorporate Easily on to Shuttle:

IMPS shall be a payload which can be easily configured on to the Shuttle which will ensure many flight opportunities without undue impact on cost or schedule. The IMPS mission and system design shall minimize the use of Shuttle resources beyond one quarter of the bay and all shared services. This includes, but is not limited to, power, cabling, communication links, location in the shuttle bay, thermal control, and use of the payload tape recorder. No design decision that compromises the objectives of the AFGL shall be made in implementing this requirement.

Standardize Instrument Interfaces:

Standardized interfaces between the instruments and the IMPS carrier shall be used to facilitate changes in the payload as late in the project as possible without drastically impacting cost. This will also allow the transfer of data in packets between the instruments and the data subsystem to provide increased flexibility as well as event-time correlation.

Common/Standard Data Interfaces

During the definition phase, a study of particular data interfaces shall be conducted and recommendations made. Criteria for evaluating the interfaces are: common usage within the aerospace community, an existing standard [e.g., military, IEEE (Institute of Electrical and Electronics Engineers)], and the existence of space-qualified or (as a minimum) military-qualified modules that support the data interface.

Collect Engineering/Science Data Packets

The NASA packet telemetry standard shall be employed on the IMPS for collecting engineering/science data packets. If, at some future time, the Air Force introduces its own standard for packet

telemetry, the IMPS project shall make an assessment and consider employing it on the IMPS.

Adapt to Changes in the Operating Environment:

The Shuttle operating environment is unparalled in its capabilities and dynamic nature when compared with rockets, balloon flights, or unmanned spacecraft. Factors which can affect instrument operations include:

- Change in launch date, shuttle trajectory, or attitude
- Failure at any level (observing instrument, IMPS payload, Shuttle payload, Shuttle communication network)
- Change in astronaut participation (illness, other Shuttle objectives, sleep cycle)
- Change in IMPS mission objectives (or any other objectives) from observing an unexpected phenomenon

The impacts that the preceding factors could have on the operation of a payload complement are magnified by the short flight duration of the Shuttle. The following requirements provide two specific design goals which, if implemented, could minimize, and in many cases eliminate, anticipated perturbations in normal payload operations.

Mission Timeline

The IMPS mission timeline shall be easily modified as a result of internally or externally generated changes in the operating environment. The response updates shall be completed within a short period of time relative to flight duration.

Command Telemetry

As a goal, the end-to-end information system shall be in-flight reconfigurable as a result of changes in the operating environment. Examples include: recovery of capability from failure and

enhancement of mission benefits as a result of under-utilization of Space Transportation System (STS) resources by other payloads.

Simplify Engineering/Science Data Distribution:

IMPS is designed to study cause and effect relationships. The cause is the polar/auroral environment which is measured by the IMPS-1 using an environmental sensors package. The effects of the environment are studied by four engineering investigations on board the IMPS-1. The IMPS-1 investigations are described in Section 2.2.

In order to gain information about the IMPS, an experimenter must have ready access to at least three sources of data: the environmental sensors package, the Shuttle ancillary data e.g., navigation and altitude information, and data from one or more of the engineering instruments. Presently, access time for Shuttle ancillary data tapes is measured in months; access time for engineering instrument data is measured in weeks.

One of the objectives of this project definition phase is to develop a strategy that will simplify distribution of the Shuttle ancillary data and will reduce access time from months to hours and from weeks to minutes or seconds.

Utilize Existing Flight-Proven Hardware to the Maximum Extent Possible:

The engineering/science subsystems selected for the IMPS flight system shall be, to the optimal extent practicable, flight-proven and standardized in order to reduce development time and minimize cost impact on the project.

Maximize Use of Existing Software Packages:

In the early days of spacecraft flight, discrete transistors were used for onboard control logic. As spacecraft design evolved, the transistors were replaced by integrated circuits. Spacecraft software is now beginning to

make a similar transition from spacecraft-unique, line-by-line assembly level code generation to software modules and highlevel languages. Software selected for the IMPS system should be, to the maximum extent practicable, off-the-shelf software modules, or modular and generated from a highlevel language.

2.2 PROJECT INSTRUMENTS

Defining the IMPS instrument system has involved synthesizing three diverse activities. First, the ESWG had met five times between 1982 and 1984 to review overall objectives and requirements for the IMPS. Second, JPL, in a series of internal studies, assessed the status of current models of the polar/auroral environment relevant to the IMPS mission, and, where possible, modified or developed simple algorithms to simulate those environments that had not been adequately examined. These algorithms were employed with the appropriate interaction models to project which instrumentation will be required to accurately characterize the operations of IMPS. Third, in the course of an interactive exchange, AFGL reviewed and, in certain instances, modified the investigations and instrument inclusion in the recommendations os ESWG, thus arriving at the final IMPS design.

2.2.1 Instrument Objectives

IMPS, as originally conceived by the AFGL, is intended to be a Shuttle-compatible payload package capable of measuring spacecraft interactions in the auroral/polar environment for Air Force (AF) space missions. Proposed AF missions require that large, high voltage structures be fielded in this environment. Since the military places greater reliance on sophisticated electronic surveillance, communications, and navigation systems capable of autonomous operation, the sensitivity of these systems to the space environment is a critical variable that must be assessed. There is, therefore, a growing urgency to evaluate the effects of the space environment on the operational capabilities of military space systems into the future. IMPS addresses this overall problem in the specific case of low altitude, high inclination polar Earth orbit (PEO), with emphasis on conjunctive operations with large structures, such as the Space Shuttle.

A systematic review of Air Force needs in concurrence with AFGL and as outlined in the American Institute of Aeronautics and Astronautics/Air Force Space Test Center (AIAA/AFSTC) Military Space Systems Technology Plan (MSSTP) has identified four functional system areas threatened by the polar/auroral environment. These functional systems areas are:

1) Optical systems as in cooled infrared detection systems. These systems are particularly sensitive to surface contamination and to the hazard of "shuttle glow" at PEO.
2) Large military structures as in the space-based radar. These structures are sensitive to variations in the environment, particularly density and radiation, which are unique to the polar/auroral environments.
3) Large, potentially highpower systems like the space-based laser. High voltage systems are affected by the high density ionospheric plasma at Shuttle altitudes, and, potentially, by spacecraft charging during auroral arc passage. Contamination and aging of structural and optical components are also of concern in the context of high power systems.
4) Manned operations, requiring EVA during passage through the auroral region. Manned spacecraft passage through the intense radiation and charging environments in the auroral and polar cap regions pose potentially serious hazards.

The above functional systems areas are derived from specific mission concepts described in the MSSTP. Examples of proposed AF space systems that are expected to be impacted by the polar/auroral environment are: IR (infrared) step-stare mosaic surveillance systems, space-based Laser Detection and Ranging System (LIDAR), neutral particle beam weapon systems, medium altitude surveillance radar, intermediate altitude phased array radar, and the space-based laser. Numerous, and potentially destructive interactions with the space environment are projected for these spacecraft systems. The potential hazards, many of which are unique to the polar/auroral cap region, will degrade systems performance and, in the case of longterm (10 or more

years) missions, may exceed the equivalent irradiation effects of nuclear weapons. The threat to AF systems must, therefore, be seriously considered and quantified wherever possible.

2.2.2 IMPS-1 Mission

The ESWG has helped JPL define the overall technical requirements of the first IMPS mission, designates IMPS-1. In pursuance to the objectives identified in Subsection 2.2.1, the IMPS-1 instrument system requirements have been formulated by applying the following criteria. The criteria are oriented to interaction types:

1) Is the interaction effect different in polar orbit than equatorial orbit?
2) Is the interaction expected to be unique to or enhanced by a particular spacecraft configuration properties?
3) Is the interaction relevant to planned AF systems?
4) Is the effect being investigated by other ongoing programs?
5) Is it appropriate or productive to carry out the investigation from the Shuttle?
6) Can useful information be made available by 1990, in order to have a meaningful impact on the next generation of AF spacecraft?

These criteria have led to the identification of four investigation categories for IMPS-1, all of which require instrumentation:

1) Dielectric charging, material property changes, and electrostatic discharge
2) High voltage solar array effects
3) Effects on space-based radars
4) Effects on space-based lasers

Another category of investigation is environmental interactions monitoring, which includes instrumentation to characterize the space environment, as well

as the environment induced by the Shuttle itself. The investigation categories and the instruments configurations supporting them are discussed in Subsection 2.2.3.

Figure 2-1 shows the relationship among the four investigation categories and the instruments currently baselined for the first IMPS flight (IMPS-1). A summary of the instrument requirements is provided in Table 2-2.

2.2.3 Instruments Descriptions

2.2.3.1 Environmental and Interactions Monitor (EIM)

Summary of Objectives:

This investigation will conduct measurements of the background plasma and the neutral environment. It will also measure variations induced by the Shuttle (wake) and the engineering/science experiments (EMI).

1) Ion and Electron Electrostatic Analyzer (ESA)

   To measure the characteristics of the precipitating charged particles in the auroral zones and polar cap.

2) Plasma Probes (PP) (Electric Field and Spherical Langmuir Probe)

   Purpose: To determine the spatial and thermal characteristics of the thermal electron population and of the electric field near the orbiter. The instrument consists of three booms with spherical sensors and an electronics unit. Two electric field sensors are installed at the extremities of the carrier. One electron density sensor, a sphere, is located on the outside of one of the E-field probes.

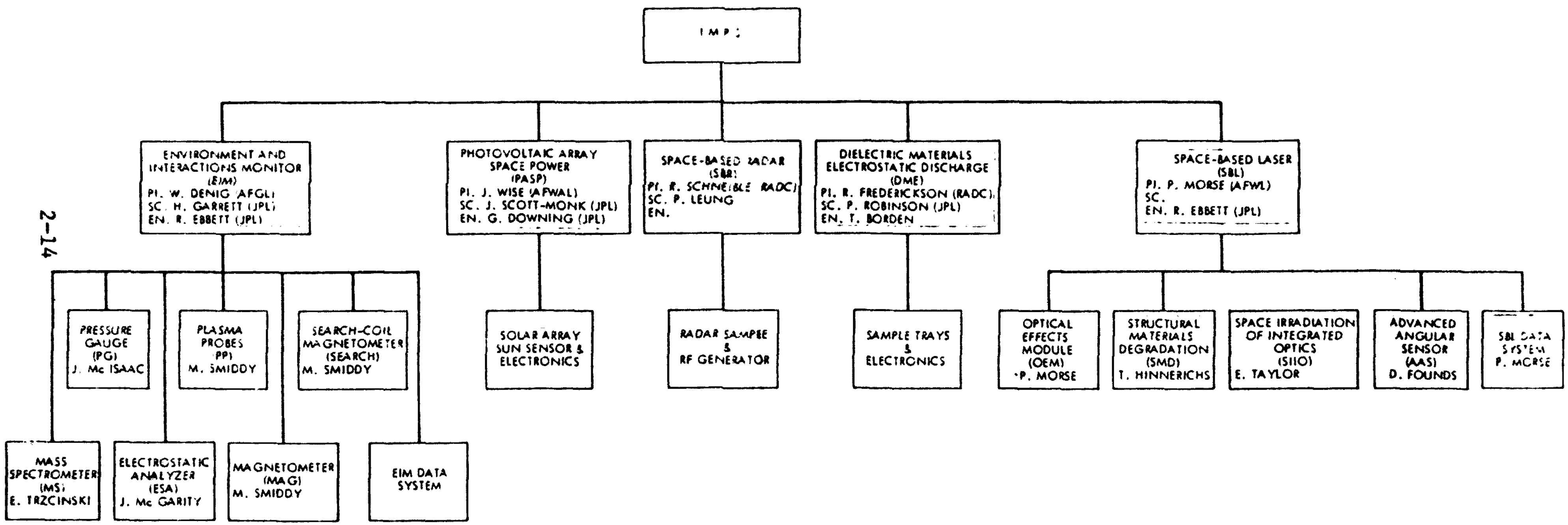


Figure 2-1. IMPS engineer/science work breakdown structure

TABLE 2-2. Instruments Requirements Summary

e = estimate

INSTRUMENT		PI	TOTAL MASS (kg)	OVERALL DIMENSIONS (cm)	FOV	POINTING DIRECTION	OPERATING RANGE (°C)	PREFERRED TEMP.	OUT of LIMIT	NON-OPERATING	NORMAL POWER (W)	PEAK POWER (W)	STANDBY POWER (W)	DATA TYPE	kbps/ ORBIT	WORD SIZE (bits)
EIM		W. DENIG AFGL														
ELECTROSTATIC ANALYZER	E I		1.86 1.86	15.2x20x21.3 15.2x20x21.3	+5°x96° +5°x96°	LOCAL ZENITH +5°	-10/50	20	-25/65	-50/100	2.6 2.6			DIGITAL	5.4×10^4	8
PLASMA PROBE	E S		2.61 0.68x3	17.8x16.8x16.8 10 Dia. x 34.3	4 Str	RAM	9/42	20	9/42	-18/107	9.5			ANALOG	5.4×10^3	8
PRESSURE GAUGE	E S		1.7 5.4	20.3x11.4x16.5 16.5x16.5x16.5	+ 30°	45° to RAM	0/30	20	-20/60	-30/75	5.6	11.5		DIGITAL	5.4×10^3	4,8
MASS. SPECT.			13.6	25.4x21.6x15.2	+20°	RAM	0/50	20	-20/70	-50/100	30.0	33.0		ANALOG	1.7×10^4	8
FLUX. MAG.	E S		1.5 0.5	15.2x15.2x7.6 7.6x7.6x10.2	4 Str		-40/60	30	-40/60	-40/60	2.0			ANALOG	4.5×10^3	16
SCH. COIL MAG.	E S		1.5 2.0	15.2x15.2x7.6 10.0x35.6x34.3	4 Str	SUN SUN + 1°	0/50	30	-20/62	-40/60	2.0			ANALOG	1.7×10^3	16
EIM DATA SYSTEM			7.3	26.7x19.3x16.5	NA	NA					18.0					
PASP	E A	J.WISE AFWAL	52.0 8.0	63.5x63.5x25.4 138.2x82.0.13	2 Str	SUN + 1 1/2°	-50/50	20	-50/50	-70/100	25.0	150.0		DIGITAL		
SBR	E A	R. SCHNEIBLE RADC		46 x 46 x 10	4 Str	EDGE TO RAM										
DME		R. FRED- ERICKSON RADC	50.0	65.8x78.8x30.5	2 Str	RAM	0/30	20	-10/40	-20/50	50.0	75.0				
SBL		P. MORSE AFWL														
OPTICAL EFF. MODULE	T T		3.0 4.5	15.2x15.2x15.2 33.3x22.2x 2.0	1°	RAM/SUN	-20/40	-10	-40/75	-55/125	4.0	8.0		DIGITAL		
STRUCT. MATL. DEGRADATION DEGRADATION	E S T		1.0 45.4 1.0	12.7x10.1x 7.6 81.2x35.6x25.4 30.5x58.4x1.3	±45° ~~2 Str~~	RAM/SUN	-15/65	20	-35/100	-35/100				DIGITAL		
ADV. ANGULAR SENSOR	E S		0.25 1.0	12.7x10.1x7.6 15.2x10.2x8.9	NA	NA	-15/65	20	-35/100	-35/100				DIGITAL		
SPACE TRR. INTEG. OPTICS		NOT IN TOTALS	50.0	40.7x122x20.3	2 Str	+ Z anti earth	-10/65	20	-55/125	-55/125	28.0	34.0		TAPE RECORDER		
SBL DATA SYSTEM			7.3	25.7x19.3x16.5	NA	NA					18.0					
TOTALS			214.25								69.3	277.5				

DATA TYPE	kbps/ ORBIT	WORD SIZE (bits)	AVERAGE kbps	BURST RATE kbps	ANALOG SAMPLING RATE	No. of COMMANDS	ALTITUDE (nm)	INCLINATION	TIME	DUTY CYCLE PWR	DUTY CYCLE DATA	ON-ORBIT OPERATIONS	EMI PRODUCTION	EMI SUSCEPTI-BILITY	CONTAMINATION PRODUCTION	CONTAMINATION SUSCEPTIBILITY	PURGE REQUIRED	COVER REQUIRED
IGITAL	5.4×10^4	8	10	< 100		9	> 150	75° - 105°	Noon - Mid.			SHUTTLE and FREE FLIGHT	YES	YES			YES	YES
NALOG	5.4×10^3	8	1.0		4Ø 50/sec 4Ø 25/sec 3Ø 1/sec 1Ø 1/sec	2		75° - 105°				SHUTTLE and FREE FLIGHT		YES			NO	NO
IGITAL	5.4×10^3	4,8,16	1.0		5Ø 16/sec 3Ø 1/sec	7						SHUTLE and FREE FLIGHT		YES			NO	YES
NALOG	1.7×10^4	8	3.4		4Ø100/sec 1Ø 10/sec 3Ø 1/sec 2Ø 1/sec	8						SHUTTLE and FREE FLIGHT	YES	YES			NO	YES
NALOG	4.5×10^3	16	0.840		20/sec	2						SHUTTLE and FREE FLIGHT	YES	YES			NO	NO
NALOG	1.7×10^3	16	0.032			2						SHUTTLE and FREE FLIGHT	YES	YES			NO	NO
							NA	NA	NA			NA	AN	NA	NA	NA	NA	NA
IGITAL			<1.0				> 290	85° - 95°	Noon - Mid.			FREE FLIGHT	YES	YES			NO	NO
							> 290					FREE FLIGHT	YES	YES			NO	NO
							> 290					SHUTTLE and FREE FLIGHT	NO	YES	NO	YES	NO	?
IGITAL			0.018			4	>290					SHUTTLE and FREE FLIGHT	YES	NO	NO	NO	YES	YES
IGITAL				6.0		3	> 290					FREE FLIGHT	YES	NO	NO	NO	NO	NO
IGITAL				96.0		2	> 290					FREE FLIGHT	YES	NO	NO	NO	NO	NO
APE ECORDER						2	> 290					SHUTTLE	YES	NO	NO	NO	NO	NO
							NA	NA	NA			NA	NA	NA	NA	NA	NA	NA
			17.29	202.0		35												

2

4 december 1984

	DUTY CYCLE PWR	DUTY CYCLE DATA	ON-ORBIT OPERATIONS	EMI PRODUCTION	EMI SUSCEPTI-BILITY	CONTAMINATION PRODUCTION	CONTAMINATION SUSCEPTIBILITY	PURGE REQUIRED	COVER REQUIRED	Oper. Day or Night	
3.			SHUTTLE and FREE FLIGHT	YES	YES			YES	YES	BOTH	
			SHUTTLE and FREE FLIGHT		YES			NO	NO	BOTH	
			SHUTLE and FREE FLIGHT		YES			NO	YES	BOTH	
			SHUTTLE and FREE FLIGHT	YES	YES			NO	YES	BOTH	
			SHUTTLE and FREE FLIGHT	YES	YES			NO	NO	BOTH	
			SHUTTLE and FREE FLIGHT	YES	YES			NO	NO	BOTH	
			NA	AN	NA	NA	NA	NA	NA	NA	
3.			FREE FLIGHT	YES	YES			NO	NO	BOTH	
			FREE FLIGHT	YES	YES			NO	NO	BOTH	
			SHUTTLE and FREE FLIGHT	NO	YES	NO	YES	NO	?	BOTH	* Thruster Plume & Water Dumps
			SHUTTLE and FREE FLIGHT	YES	NO	NO	NO	YES	YES	BOTH	
			FREE FLIGHT	YES	NO	NO	NO	NO	NO	BOTH	
			FREE FLIGHT	YES	NO	NO	NO	NO	NO	BOTH	
			SHUTTLE	YES	NO	NO	NO	NO	NO	BOTH	
			NA	NA	NA	NA	NA	NA	NA	NA	

3

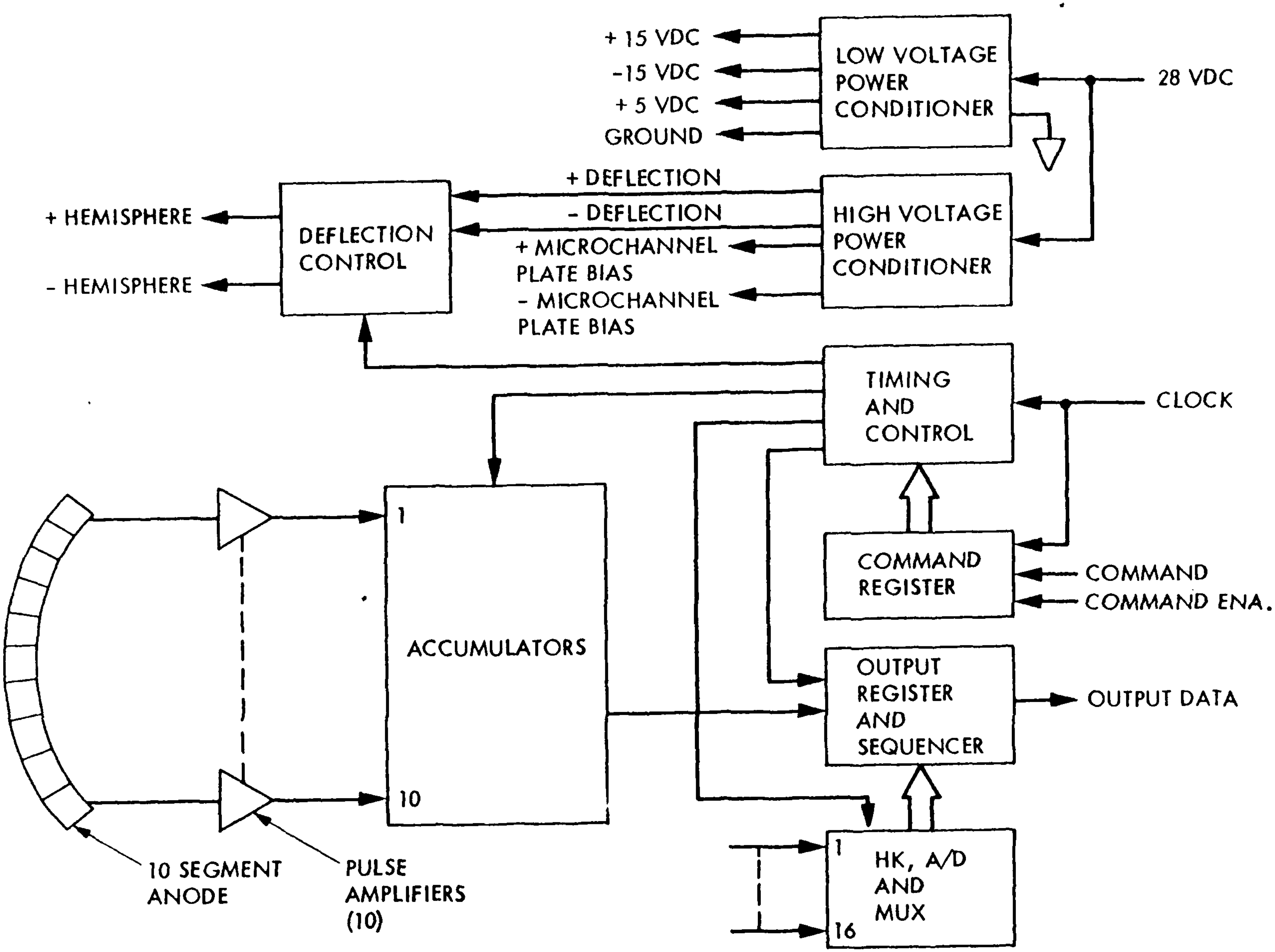


Figure 2-2. Electrostatic Analyzer Functional Block Diagram

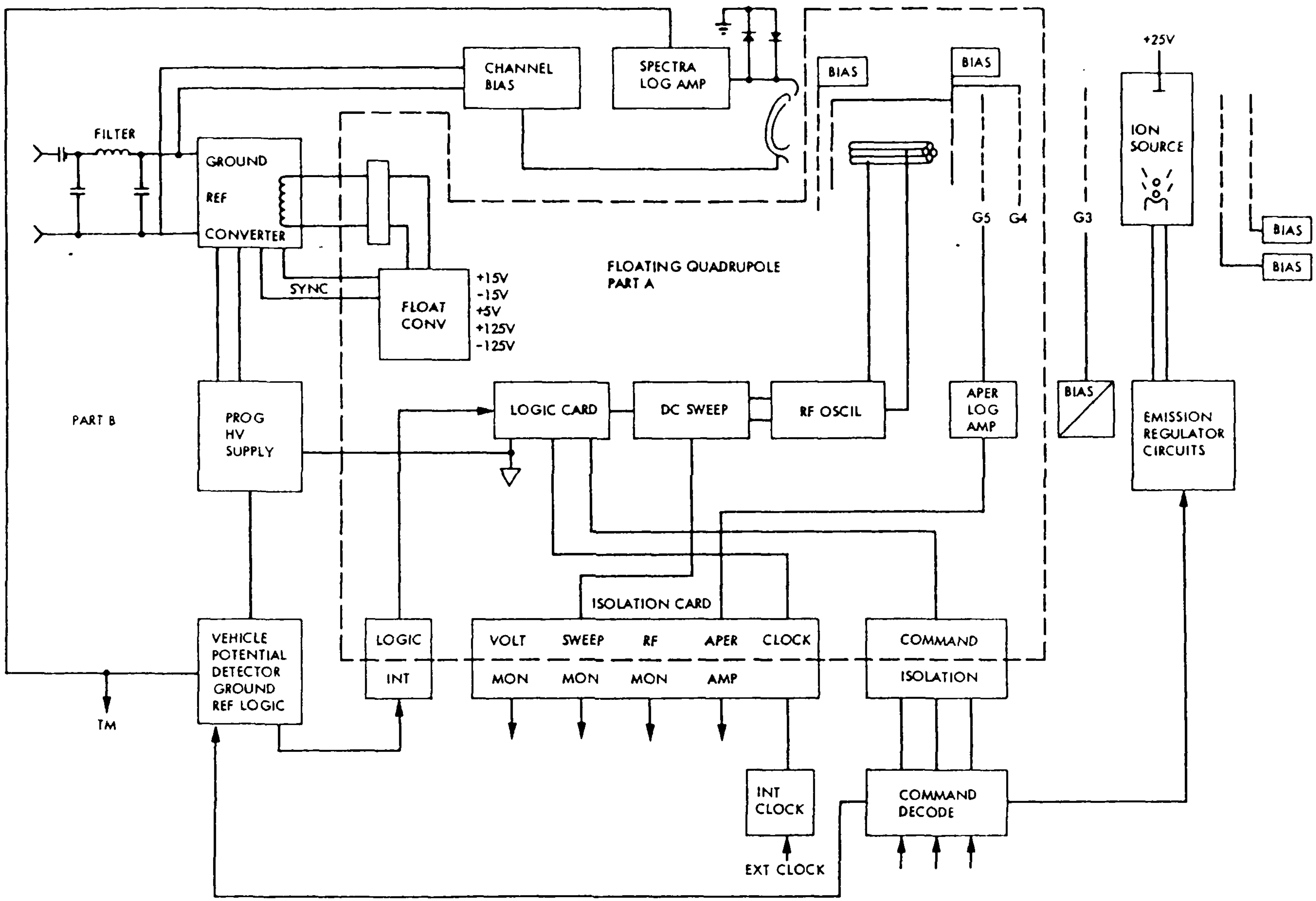


Figure 2-3. Mass Spectrometer Functional Block Diagram

5) Magnetometer (MAG)

Purpose: To measure the geomagnetic field insitu and DC offsets due to currents and low frequency oscillations.

6) Search Coil Magnetometer (SEARCH)

Purpose: To measure all magnetic field variations and determine which observed disturbances are electrostatic and which are electromagnetic.

2.2.3.2 High Voltage Solar Array (HVA)

Future space missions are expected to require power in the magnitude of 5 kW, with peaks to 50 kW, provided by large solar array and using new materials. This investigation will be designed to evaluate the components for the new generation of large, high voltage/high power arrays for deployment in the auroral environment. The specific objectives of this investigation are to determine the effects of environmentally generated electromagnetic interference (EMI) noise on solar array power systems; characterize power loss to the plasma; estimate component damage due to arcing; and determine the operating characteristics of GaAs solar cells.

The HVA instrument will consist of a solar array panel with the following components mounted to it:

1) Silicon solar cell module of 600 cells (2 x 4 cm) arranged in a single circuit, 2 cells wide by 300 cells long (0.5 M^2)
2) GaAs solar cell module of 200 cells (2 x 2 cm) arranged in a single circuit, 2 cells wide by 100 cells long (0.1 M^2)
3) Cassegrainian concentrator module of 8 concentrators, 15.2 x 15.1 cm (0.025M^2)
4) SLATS concentrator module, 3 slats, 22.8 cm wide x 30.15 cm long (0.075 M^2)

5) Integral covered (PAS) silicon cell module, 15.2 x 15.2 cm ($0.025\ M^2$)

6) A sun sensor to determine actual sun incidence angle when data is taken

7) A Langmuir Probe to measure the plasma environment

8) Temperature sensors (5) on each module

The other part of the HVA instrument constitutes the electronics box which contains the following components:

1) DC current monitor

2) AC current monitor

3) Sequencer, including command link, clock, commutator, and real time data control

4) Bias voltage power supply

5) Leakage current sensors, AC to DC noise (pulse monitor)

6) Main power supply

7) *Temperature monitoring electronics*

8) Heaters and controller

9) Bias voltage generator to bias the modules in increments of: 0, +50, +150, +300, +500, -50, -300 and -500 volts

A simplified block diagram of the HVA is presented in Figure 2-4.

2.2.3.3 Space-Based Radar (SBR)

An actual sample of a Space-Based Radar antenna will be configured on IMPS to investigate the effects of plasma interactions with the SBR as functions of plasma density and Shuttle orientation. This investigation will allow the SBR operation to be characterized in the IMPS environment.

The antenna is a structure composed of an aluminum sheet surrounded by an array of dipoles mounted on kapton membranes.

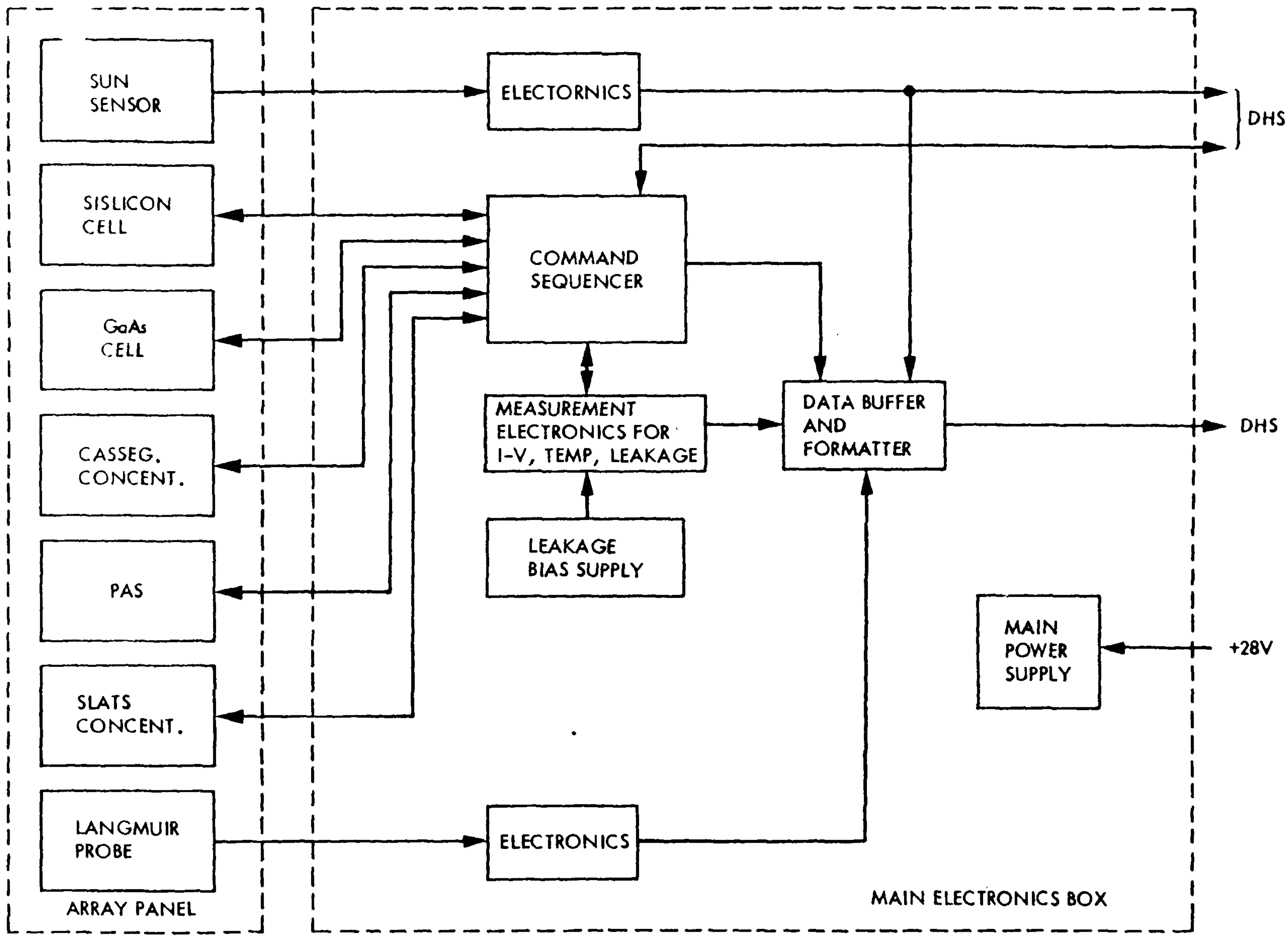


Figure 2-4. Block Diagram - High Voltage Solar Array (HVA)

2.2.3.4 Dielectric Materials Electrostatic Discharge (DME)

This investigation will measure the internal charging and potential breakdown of dielectric materials due to bombardment by electrons with energies of 10 - 100 keV.

It is expected that the energetic, precipitating auroral particle fluxes associated with polar orbits will cause significant degradation of surface and of bulk materials' electrical properties. The DME investigation will seek to characterize and quantitify the degredation of the various materials.

The DME investigation consists of standard sample trays, each tray containing up to 100 samples. These trays have grids over the trays to simulate the wake condition by biasing out the positive ions while letting the electrons continue to bombard the samples. Pulsing will be monitored on the sample using electrodes wired to pulsed current detectors. Several electrode configurations will be used because large structures will contain a large variety of dielectric materials. Pulsing will be measured through the following paths:

1) An electrode to ground
2) Two electrodes on the same surface of a sample tray
3) Two electrodes on differing surfaces of the same sample
4) An electrode and the ring/grid

A simplified block diagram of the DME is presented in Figure 2-5.

2.2.3.5 Space-Based Laser (SBL)

This investigation will study environmental effects on large optics structural materials, on optical material properties, and on the changes of

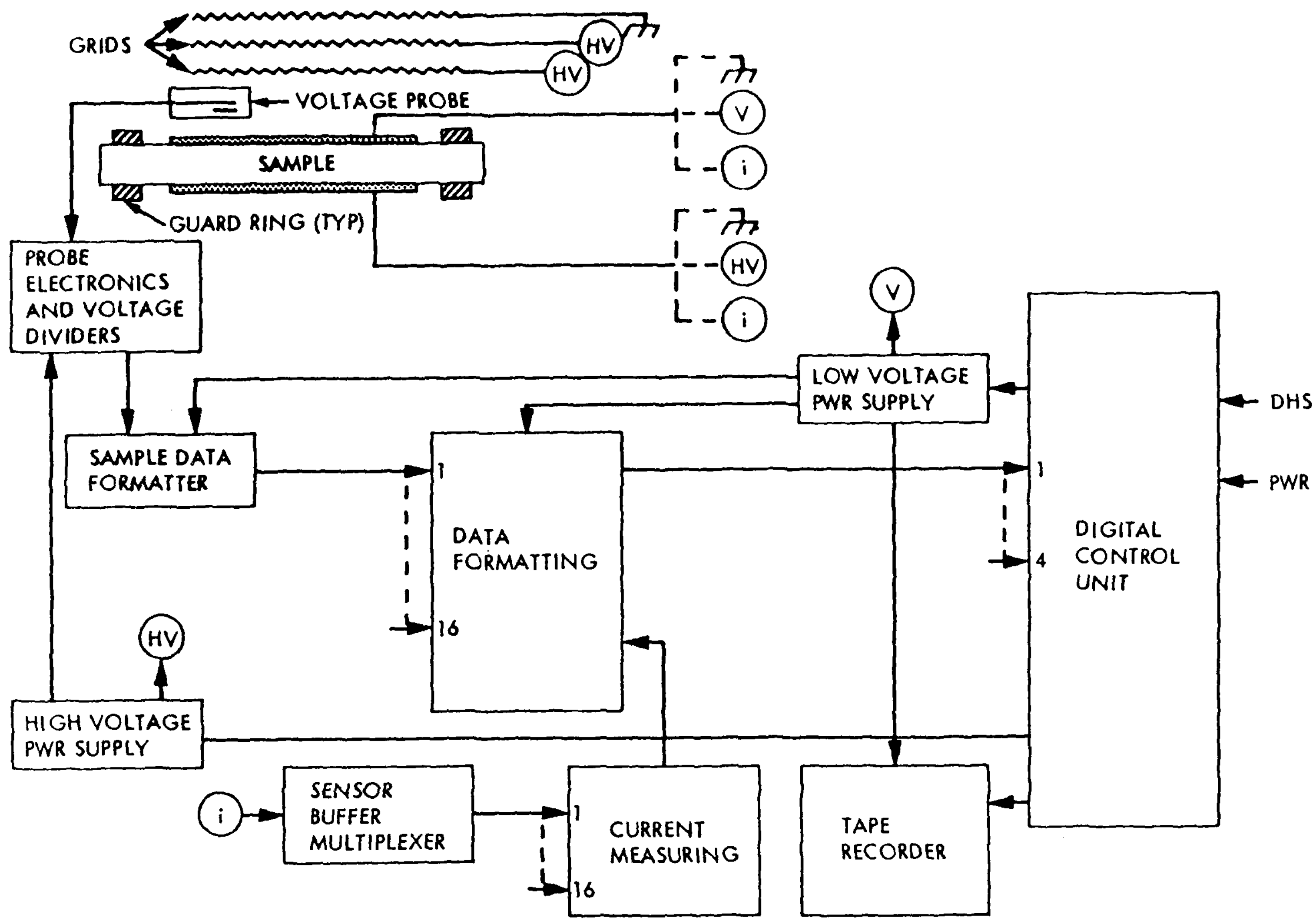


Figure 2-5. Dielectric Materials Electrostatic Discharge Functional Block Diagram

active and passive structural control techniques over time. The SBL instrument consists of four components:

1) Optical Effects Module (OEM)
2) Structural Materials Degradation (SMD)
3) Advanced Angular Sensor (AAS)
4) Space Irradiation of Integrated Optics (SIIO)

The four SBL components are described below:

Optical Effects Module (OEM)

This component will provide data on contamination hazards likely to be encountered by the optical components of space-borne instrumentation. The optical degradation of some typical mirror materials will be measured and monitored. Optical property changes caused by the deposition of particulates and molecular films will also be measured, utilizing a spectular reflectance measurement device. The OEM instrument consists of a light source, intermediate focusing and collecting optics, a rotatable sample carousel, and a Photo Multiplier Tube (PMT). The instrument will also include a sample tray of optical materials.

Structural Materials Degradation (SMD)

This component will characterize possible changes in passive damping materials in the polar space environment to avoid subsequent degradation impacts on the system. It will also measure strength degradation of composite materials. The SMD instrument will consist of a tuning fork design with damping material attached, along with a dynamic disturbance device and accelerometers to measure the effects. The instrument will also include a tray with passive samples of composite materials.

Advanced Angular Sensor (AAS)

This component will determine the effects of the space environment, in particular radiation and strong magnetic fields, on actuators and sensors. These sensors (2) are magneto-hydrodynamic effect devices that will be mounted back to back.

Space Irradiation of Integrated Optics (SIIO)

The instrument will consist of active integrated optical devices (IOD) and fiber optics (FO) wave guides operating as a C^3 system. The instrument will correlate the expected 1600 rad dose effects of the polar orbit with those of the AFWL (LDEF) experiment performed by orbiting through the Van Allen radiation belts.

2.2.4 Trajectory Requirements

The IMPS will be launched from Vandenburg AFB, California via the Space Shuttle. The IMPS will first orbit with the Shuttle and then be released to free-fly. After TBD days, the IMPS will be recovered and returned to earth. The altitude and attitudes for the mission have yet to be defined. Preliminary instrument trajectory of time, attitude, and altitude requirements are listed in Table 2-3.

2.2.5 Physical Properties

Table 2-4 identifies the physical properties of IMPS-1 and its various components.

2.2.6 Environmental Requirements

The temperature requirements for the IMPS-1 instruments are specified in Table 2-5. Regarding cover deployment, the carrier shall supply

TABLE 2-3. Time, Attitude and altitude Requirements

Instrument	Altitude (NM)	Orbit Type	Time
ELECTROSTATIC ANALYZER	ß150	75^{o}-105^{o}	Noon-Mid
PLASMA PROBE	-	75^{o}-105^{o}	-
PRESSURE GUAGE	-	-	-
MASS SPECTROMETER	-	-	-
MAGNETOMETER	-	-	-
SEARCH COIL MAGNETOMETER	-	-	-
HIGH VOLTAGE SOLAR ARRAY	ß290	85^{o}-95^{o}	Noon-Mid
SPACE BASED RADAR	ß290		
DIELECTRIC MATERIALS	290		
ELECTROSTATIC DISCHARGE			
OPTICAL EFFECTS MODULE			
STRUCTURAL MATERIALS DEGRADATION			
ADVANCED ANGULAR SENSOR	290		
SPACE IRRADIATION OF INTEGRATED OPTICS	290		

TABLE 2-4. IMPS-1 Instrument Physical Properties

Instrument	MASS (Kg)	Power	Dimension (cm)
ESA (E)	1.86	2.6	15.2 x 20 x 21.3
ESA (I)	1.86	2.6	15.2 x 20 x 21.3
PP (E)	2.61	9.5	17.8 x 16.8 x 16.8
PP (S), (3)	0.68	-	10.0 Dia. x 34.3
PG (E)	1.7	5.6-11.5	20.3 x 11.4 x 16.5
PG (S)	5.4	-	16.5 x 16.5 x 16.5
MS	13.6	30-33	25.4 x 21.6 x 15.2
MAG (E)	1.5	2.0	15.2 x 15.2 s 7.6
MAG (S)	0.5	-	7.6 x 7.6 x 10.2
SEARCH (S)	2.0	0	10.0 x 35.6 x 34.3
SEARCH (E)	1.5	2.0	7.6 x 7.6 x 10.2
HVA (E)	52.0	25-150	63.5 x 63.5 x 25.4
HVA (A)	8.0		138.2 x 82 x 0.13
SBR (E)			
SBR (A)			46.0 x 96.0 x 10.0
DME	50	50-75	65.8 x 78.8 x 30.5
OEM	3.0	4-8	28.0 x 45.7 x 25.4
OEM (T)	4.5		
SMD (E)	1.0	20*	12.7 x 10.1 x 7.6
SMD (S)	45.4		81.2 x 35.6 x 25.4
SMD (T)	1.0		30.5 x 58.4 x 1.3
AAS (E)	0.25	20*	5.1 x 3.9 x 3.9
AAS (S)	1.0		15.2 x 10.2 x 8.9
S110 (Shuttle Bay)	50	28.34	40.7 x 122 x 20.3

* Conservative estimates

TABLE 2-5. Temperature Requirements For IMPS-1 Instruments

Temperature Requirements			
OPERATING RANGE			NON-OPERATING RANGE
Instrument	Preferred	In Limit	
ESA	+20°	-10°C to +50°C	-50°C to +100°C
PP	+20°C	+9°C to +42°C	-18°C to +107°C
PG	+20°C	0°C to +30°C	-30°C to +75°C
MS	+20°C	0°C to +50°C	-50°C to +100°C
MAG	+30°C	-40°C to +60°C	-40°C to +60°C
SEARCH	+30°C	0°C to +50°C	-40°C to +60°C
HVA	+20°C	-50°C to +50°C	-70°C to +100°C
SBR			
DME	+20°C	0°C to +30°C	-20°C to +50°C
OEM	-10°C	-20°C to +40°C	-55°C to +125°C
SMD	+20°C	+5°C to +65°C	-35°C to +100°C
AAS	+20°C	-15°C to +65°C	-35°C to +100°C
S110	+20°C	-10°C to +65°C	-50°C to +125°C

commands and signal pulses for each instrument. Each instrument will be provided its cover design, deployment mechanism, and covers.

2.2.7 Pointing Requirements

Table 2-6 lists the look angle requirements for IMPS-1 instruments.

2.2.8 Instrument Data Requirements

The preliminary instrument data requirements are detailed in Table 2-7.

2.2.9 Command Requirements

The IMPS-1 carrier accepts, processes and transmits commands to the E/S instruments. The number of commands needed by each E/S instruments is listed in Table 2-7. The following paragraphs identify the commands required by each one of the E/S instruments on IMPS-1.

Electrostatic Analyzer (ESA):

The ESA requires the following nine commands:

1) Main Power On
2) Main Power Off
3) High Voltage On
4) High Voltage Off
5) Background Mode (Def. = 0)
6) Normal Mode (30 keV to -30 eV)
7) Low Range (1 keV to -30 eV)
8) Medium Range (30 keV to -5 keV)
9) High Range (30 keV to -5 keV)

Plasma Probes (PP):

TABLE 2-6. Look Angle Requirements for IMPS-1 Instruments

	FOV	VIEWING DIRECTION	ACCURACY
ESA	$\pm$ 5° & 96°	Local Zenith	$\pm$ 5°
PP	4 STR	RAM	
PG	$\pm$ 30°	45° to RAM	
MS	$\pm$ 20°	RAM	
MAG	4 STR		
SEARCH	4 STR	SUN $\pm$ 1°	
HVA	2 STR	SUN $\pm$ 1-1/2°	$\pm$ 1°
SBR	4 STR	EDGE to RAM	
DME	2 STR	SPACE/SUN/EARTH	
OEM	1°	RAM/SUN	$\pm$ 0.1°
SMD	$\pm$45°	8 RAM/SUN	
AAS	2 STR	N/A	
SIIO	2 STR	+Z (ANTIEARTH)	$\pm$30°

TABLE 2-7. Instrument Data Requirements

Instrument	Digital Average Kbps	Burst Kpbs	Analog Sampling Rate	No. of Commands
ESA	10	100	-	9
pp	1.0		4 @ 50/sec 4 @ 25/sec 3 @ 1/sec 1 @ 1/sec Discrete	2
PG	1.0		5 @ 16/sec 3 @ 1/sec	7
MS	3.4		4 @ 100/sec 1 @ 10/sec 3 @ 1/sec 2 @ 1/sec	8
MAG	0.84		20/sec	2
SEARCH	0.032			2
HVA				4
Sun Sensor				
SBR				
DME				2
OEM	0.018			2
SMD		6.0		3
AAS		96.0		2
SIIO*	0	0		2

*internal tape recorder

The PP requires the following two commands:

1) Main Power On
2) Main Power Off

Pressure Gauge (PG):

The PG requires the following seven commands:

1) Main Power On
2) Main Power Off
3) Baffle Out
4) Baffle In
5) Cover Deploy
6) Baffle Mode 1
7) Baffle Mode 2

Mass Spectrometer (MS):

The MS requires the following eight commands:

1) Main Power On
2) Main Power Off
3) Cap Power On
4) Cap Power Off
5) Cap Select Open
6) Cap Select Closed
7) Mode I
8) Mode II

Magnetometer (MAG):

The MAG requires the following two commands:

1) Main Power On
2) Main Power Off

Search Coil Magnetometer (SEARCH):

The SEARCH requires the following two commands:

1) Main Power On
2) Main Power Off

High Voltage Solar Array (HVA):

The HVA requires the following four commands:

1) Main Power On
2) Main Power Off
3) Sequencer Control
4) Sun Sensor Data

Space-Based Radar (SBR):

The SBR command requirements have not yet been defined.

Dielectric Materials Electrostatic Discharge (DME):

The DME requires the following two commands for the Shuttle-mounted instrument:

1) Main Power On
2) Main Power Off

Optical Effects Module (OEM):

The OEM requires the following four commands:

1) Main Power On
2) Main Power Off
3) Open Cover
4) Close Cover

Structural Materials Degradation (SMD):

The SMD requires the following two commands:

1) Main Power On
2) Main Power Off

Advanced Angular Sensor (AAS):

The AAS requires the following two commands:

1) Main Power On
2) Main Power Off

Space Irradiation of Integrated Optics (SIIO):

The SIIO requires the following two commands:

1) Main Power On
2) Main Power Off

2.2.10 Engineering/Science Observations

The IMPS-1 overall objective is to obtain environmental interactions data while located in the Shuttle, as well as a free flyer away from the Shuttle. For effective E/S observations while the IMPS is free flying, it is necessary to orient its instruments to view the sun whenever possible, place instruments in the ram and in the wake, and position the Shuttle to put the IMPS-1 into the wake of the Shuttle. The correlation between the various IMPS-1 instruments and the two optional modes of the IMPS-1, Shuttle mounted or free flyer, is presented below.

Ion And Electron Electrostatic Analyzer (ESA):

These instruments will operate both in the Shuttle and in free flight.

Plasma Probes (PP):

This instrument will operate both in the Shuttle and in free flight.

Pressure Gauge (PG):

This instrument will operate both in the Shuttle and in free flight.

Ion/Neutral Quadrupole Mass Spectrometer (MS):

This instument will operate both in the Shuttle and in free flight.

Search Coil Magnetometer (SEARCH):

This instrument will operate both in the Shuttle and in free flight.

High Voltage Solar Array (HVA):

This instrument will operate only in free flight.

Space-Based Radar (SBR):

This instrument will operate only in free flight.

Dielectric Materials Electrostatic Discharge (DME):

This instrument will operate both in the Shuttle and in free flight.

Optical Effects Module (OEM):

This instrument will operate only in free flight.

Structural Materials Degradation (SMD):

This instrument will operate only in free flight.

Advanced Angular Sensor (AAS):

This instrument will operate only in free flight.

Space Irradiation Of Integrated Optics (SIIO):

This instrument will operate only in the Shuttle. It will not be mounted on the carrier.

2.2.11 Instrument Test and Calibration

All calibration measurements will be performed before instrument delivery to the integration contractor. No calibrations will be done once the instruments are mounted on the carrier.

PREFLIGHT TEST REQUIREMENTS

ENVIRONMENT AND INTERACTIONS MONITOR (EIM)

Prior to EIM system delivery, each IMPS-1 instrument will be thoroughly tested to ensure that it meets its required performance parameters. The instruments will then be integrated into the EIM system, and system checkout will be performed. Extensive engineering testing will be subsequently performed to verify that all the configured instruments function as a system.

Carrier Integration

Following delivery to the integration contractor, the EIM system will be mounted on the carrier. Interface testing will be

performed to establish that the appropriate interfaces are provided both in the system and in the carrier. Once the interface checks out, an integration verification test will be performed to evaluate system performance via the carrier system.

Pre-Launch Test

A minimal pre-launch test is planned at Vandenburg AFB. Electrical functional tests will be performed along with end-to-end system performance verification.

HIGH VOLTAGE SOLAR ARRAY (HVA)

Prior to instrument delivery, the HVA instrument will be thoroughly tested to ensure that it meets its required performance paramenters.

Carrier Integration

Following delivery to the integration contractor, the HVA instrument will be mounted on the carrier. Interface testing will be performed to establish that the appropriate interfaces are provided both in the instrument and in the carrier. After the interface checks out, an integration verification test will be performed to evaluate instrument performance via the carrier system.

Pre-Launch Test

A minimal pre-launch test is planned at Vandenburg AFB. Electrical functional tests will be performed along with end-to-end system performance verification.

SPACE BASED RADAR (SBR)

Prior to instrument delivery, the SBR instrument will be thoroughly tested to ensure that it meets its required performance parameters.

Carrier Integration

Following delivery to the integration contractor, the SBR instrument will be mounted on the carrier. Interface testing will be performed to establish that the appropriate interfaces are provided both in the instrument and in the carrier. After the interface checks out, an integration verification test will be performed to evaluate instrument performance via the carrier system.

Pre-Launch Test

A minimal pre-launch test is planned at Vandenburg AFB. Electrical functional tests will be performed along with end-to-end system performance verification.

DIELECTRIC MATERIALS ELECTROSTATIC DISCHARGE (DME)

Prior to instrument delivery, the DME instrument will be thoroughly tested to ensure that it meets its required performance parameters.

Carrier Integration

Following delivery to the integration contractor, the DME instrument will be mounted on the carrier. Interface testing will be performed to establish that the appropriate interfaces are provided both in the instrument and in the carrier. After the interface checks out, an integration verification test will be performed to evaluate instrument performance via the carrier system.

Pre-Launch Test

A minimal pre-launch test is planned at Vandenburg AFB. Electrical functional tests will be performed along with end-to-end system performance verification.

SPACE BASED LASER (SBL)

Prior to SBL system delivery, each instrument will be thoroughly tested to ensure that it meets its required performance parameters. The instruments will then be integrated into the SBL system, and system checkout will be subsequently performed to verify that all the configured instruments function as a system.

Carrier Integration

Following delivery to the integration contractor, the SBL system will be mounted on the carrier. Interface testing will be performed to establish that the appropriate interfaces are provided both in the instrument and in the carrier. Once the interface checks out, an integration verification test will be performed to evaluate instrument performance via the carrier system.

Pre-Launch Test

A minimal pre-launch test is planned at Vandenburg AFB. Electrical functional tests will be performed along with end-to-end system performance verification.

SECTION 3
MISSION DESIGN

3.1 TRAJECTORY

3.1.1 Launch Trajectory

Launch Period:

The science instruments of the IMPS are designed to measure the environment of the general background space environment and, more specifically, that of an auroral event in the auroral zones. It is easiest for ground-based stations to observe an auroral event for flight data correlation when there is darkness in the auroral zones. Therefore, the most desirable launch period would be the time that allows for the maximum amount of darkness. Because there are more ground stations in the northern hemisphere than in the southern, the most desirable launch period would be winter in the northern hemisphere. A less desirable launch period would be winter in the southern hemisphere. The least desirable launch period would be in the spring or autumn of either the northern or southern hemispheres because these times allow the least amount of darkness over the polar auroral zones.

Launch Window:

Some of the IMPS instruments need to operate in sunlight, and others, in darkness. For those observing darkness, the best type of orbit is one offering the maximum amount of time in Earth shadow. This would be a "noon-midnight" orbit; its ascending and descending nodes pass midway between the sunrise and sunset terminator lines on the surface of the Earth on both the sunlit and dark sides. This type of orbit has two launch windows for each day in the launch period. One launch window is centered near noon local time at the launch site and the other is centered near midnight local time at the launch site. The actual launch time would be planned so that orbital injection would occur at one of these times (taking into account a nominal Shuttle Orbiter ascent trajectory sequence). It would be possible to achieve

a noon-midnight orbit with either launch window but operational constraints by the payload and STS could limit the orbit to only one. Some of the operational constraints to be considered include: designing mission sequence plans for each of the launch windows; increasing personnel support for two launch opportunities per day, and being prepared for nominal launch and land sites (and contingency landing sites) for both daylight and darkness.

For a fixed azimuth Shuttle ascent trajectory, in order to achieve an exact noon-midnight orbit, the launch window will have no duration. This means that it is necessary to launch at one, and only one, time in each launch window which occurs twice per day for each day in the launch period. If the launch time is missed, it will be necessary to wait until the next launch window (12 or 24 hours later) for another launch opportunity.

If it were possible to have a longer launch window duration of, for example, one hour, the probability of launching on the first day of the launch period would be greatly increased. That one hour would allow for last minute details and repairs if necessary. The problem with an extended duration is that a delay, for example, of one hour would cause a 15 degree longitudinal shift away from the midway point between the sunrise and sunset terminator lines; this reduces the amount of orbit time in the darkness of the Earth shadow.

Thus, the benefits of an increased launch duration must be weighed against the loss of orbit time in darkness.

Orbital Injection Requirements:

The instruments on IMPS require a minimum orbit altitude of 150 n mi and most should go as high as possible in order to adequately characterize the operating environment for future operational systems. The launch vehicle must be able to place the total mass of the IMPS, plus the mass of the cargo partners, into the chosen orbit. The current STS performance capability for a 150 n mi altitude orbit is shown in Figure 3-1.

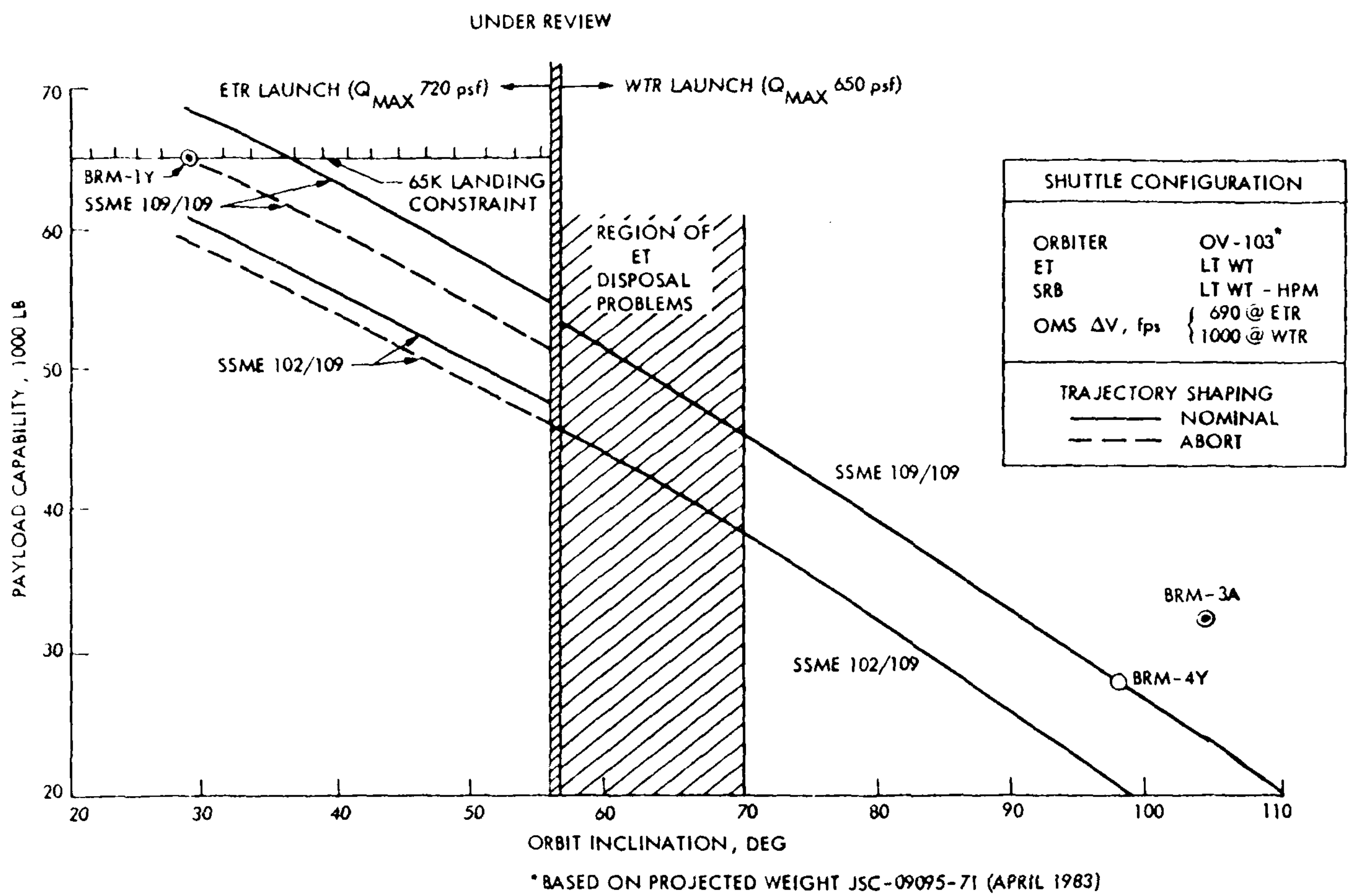


Figure 3-1. Space Shuttle payload deployment capability vs incilination

To achieve the maximum possible altitude at some point in the orbit, an elliptical orbit could be used. If an elliptical orbit were used, it would be desirable for the apogee point of the orbit to be over one of the polar auroral zones. Because of the location of the launch site (Vandenberg Air Force Base), with respect to the auroral zones near the poles, an elliptical orbit would require either a direct injection ascent trajectory (to a point in the orbit between the perigee and apogee) or a multiple burn injection sequence. The direct injection method would have an associated propellant weight penalty because injection at a point other than the perigee of the orbit is less efficient. In order to inject at the perigee point, a multiple burn sequence could be utilized where the initial ascent trajectory placed the spacecraft into a circular parking orbit with an altitude equal to the desired perigee altitude of the final elliptical orbit. Another burn would be done at the perigee point in the orbit to raise the apogee altitude to the desired value. An elliptical orbit would experience a rotation of the line of apsides because of the Earth's oblateness; this is a function of the orbit altitude and inclination as shown in Figure 3-2. The apogee would not remain over the polar auroral zones except at an inclination of 63.4 degrees; this would give very poor coverage of the polar auroral zones and could not be achieved by a direct injection launch of the STS because of problems disposing of the Space Shuttle Vehicle external tank. The launch azimuth and orbit inclination limits for launches with the STS are shown in Figure 3-3. A circular orbit with a lower constant altitude would have a simpler and more efficient injection strategy, and would probably enhance the possibility of mixing with other payloads.

The orbit inclination for the IMPS mission should be chosen after evaluating several factors. The major objective is to choose an orbit in which the spacecraft can spend its maximum amount of time in and passing through the polar auroral zones. The inclination should be high enough so that the spacecraft passes through one of the polar auroral zones twice per orbit -- the maximum number possible. With reference to the geographic location of the auroral zones, the inclination would need to be within several degrees of 90 for this to occur.

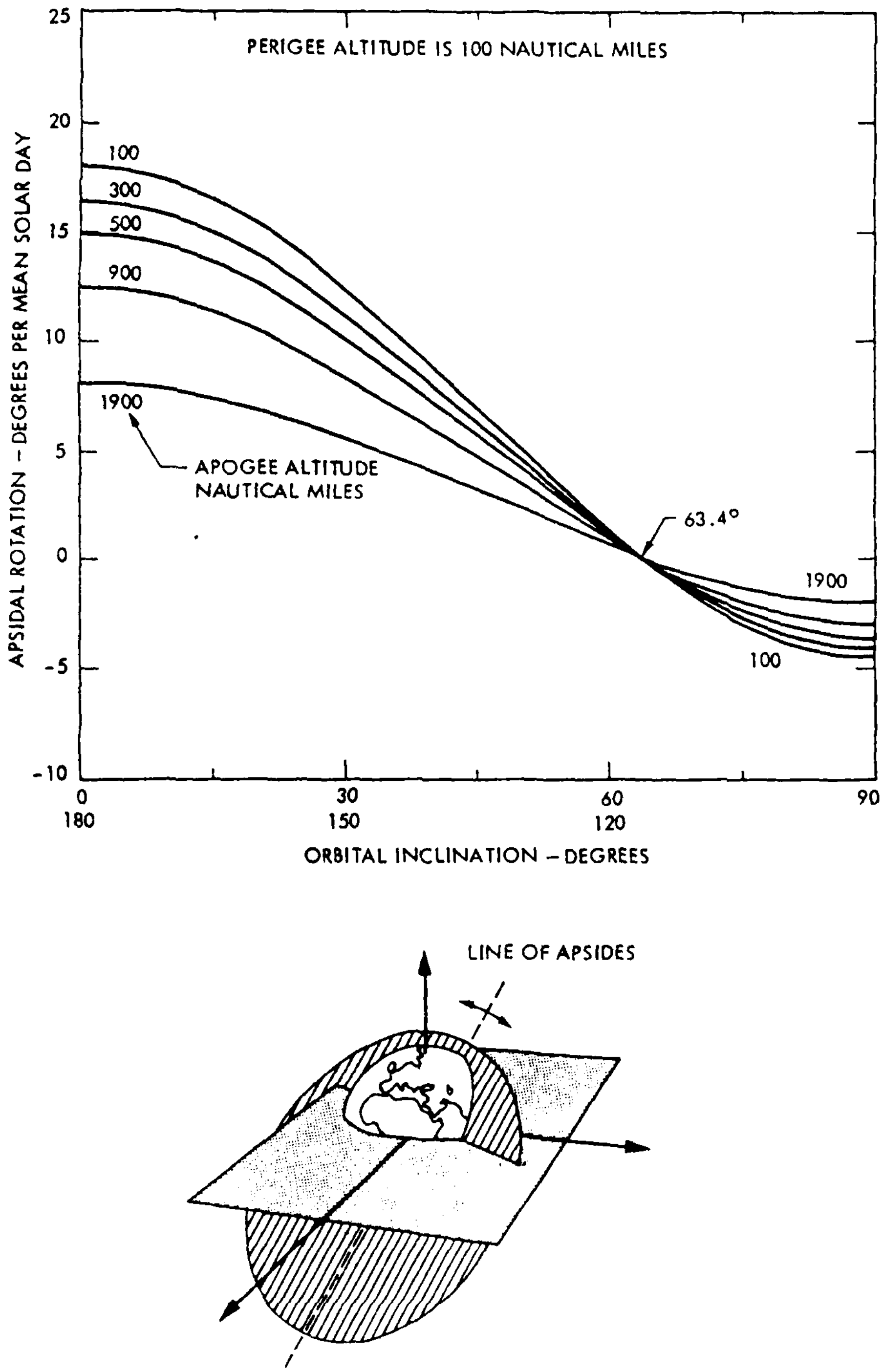


Figure 3-2. Apsidal rotation

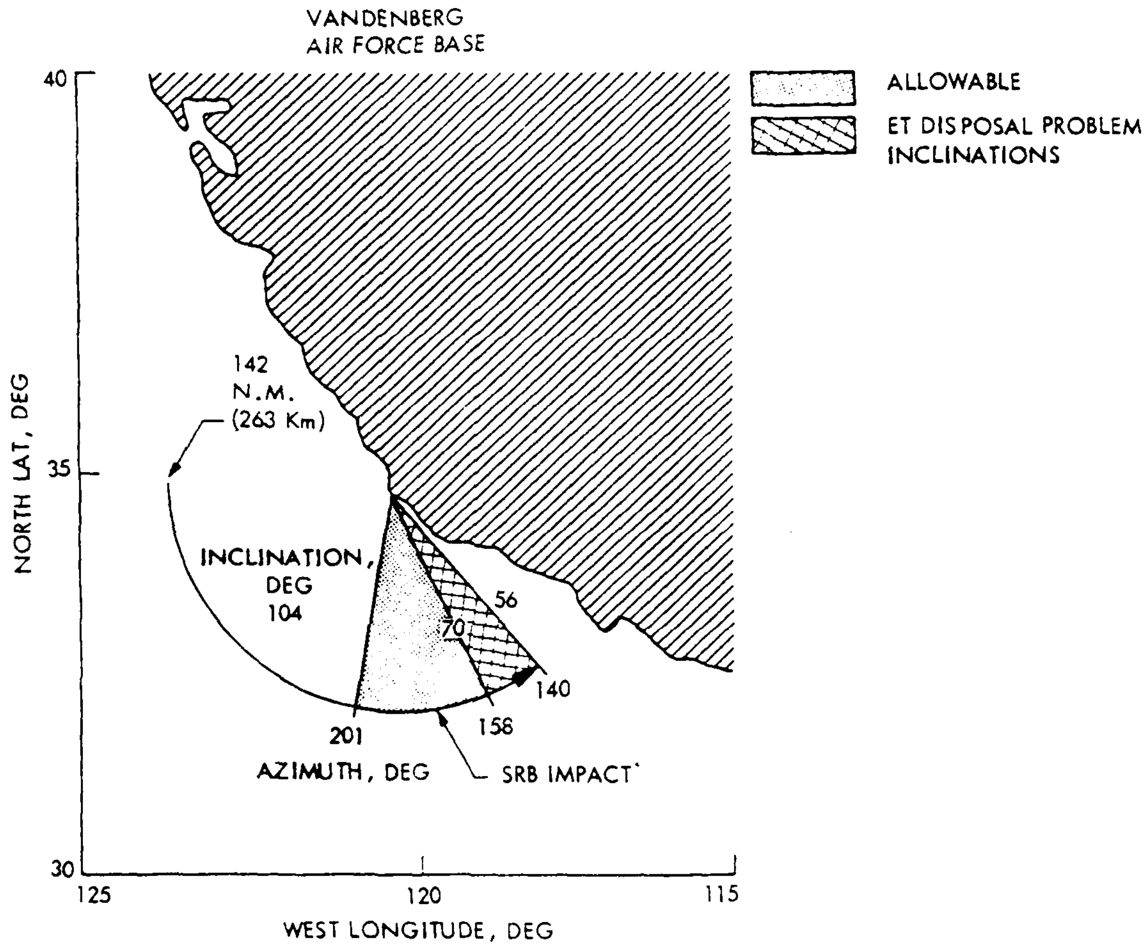


Figure 3-3. Launch site azimuth and inclination limits

Even if the spacecraft were injected into a perfect noon-midnight orbit, the orbit would tend to drift away from its orientation at the rate of approximately one degree per day because of the motion of the Earth around the Sun. The drift reduces the amount of darkness per orbit. The only way to maintain the noon-midnight orientation is for the line of nodes of the orbit to regress eastward at the rate of approximately one degree per day. The nodal regression rate because of the Earth's oblateness is a function of the orbit altitude and inclination. As shown in Figure 3-4, orbits with a nodal regression rate of approximately one degree per day eastward, at orbit altitudes between 100 and 500 nautical miles, require inclination ranges between approximately 96 and 99 degrees. For an orbit inclination of 90 degrees, there is no nodal regression. As the inclination increases, there is a reduction in the launch vehicle performance.

To select an orbit inclination, the two options must be compared: a near 90 degree inclination would have some loss of darkness because of drift away from a noon-midnight orientation; a higher degree inclination with a constant noon-midnight orientation would lose some auroral zone coverage, but would have a longer period of darkness.

An orbit inclination of less than 90 degrees would have a considerable reduction in the amount of darkness because of westward nodal regression, but launch vehicle performance would increase and the orbit could be at a higher altitude. An orbit inclination of more than 90 degrees would offer a greater amount of darkness because of eastward nodal regression but launch vehicle performance would decrease and the orbit would be at a lower altitude.

If the priorities of the IMPS objectives are: auroral zone coverage first, maximum amount of darkness second, and maximum altitude third, the optimum orbit would be a 92 degree inclination circular orbit at the maximum altitude allowed by launch vehicle performance.

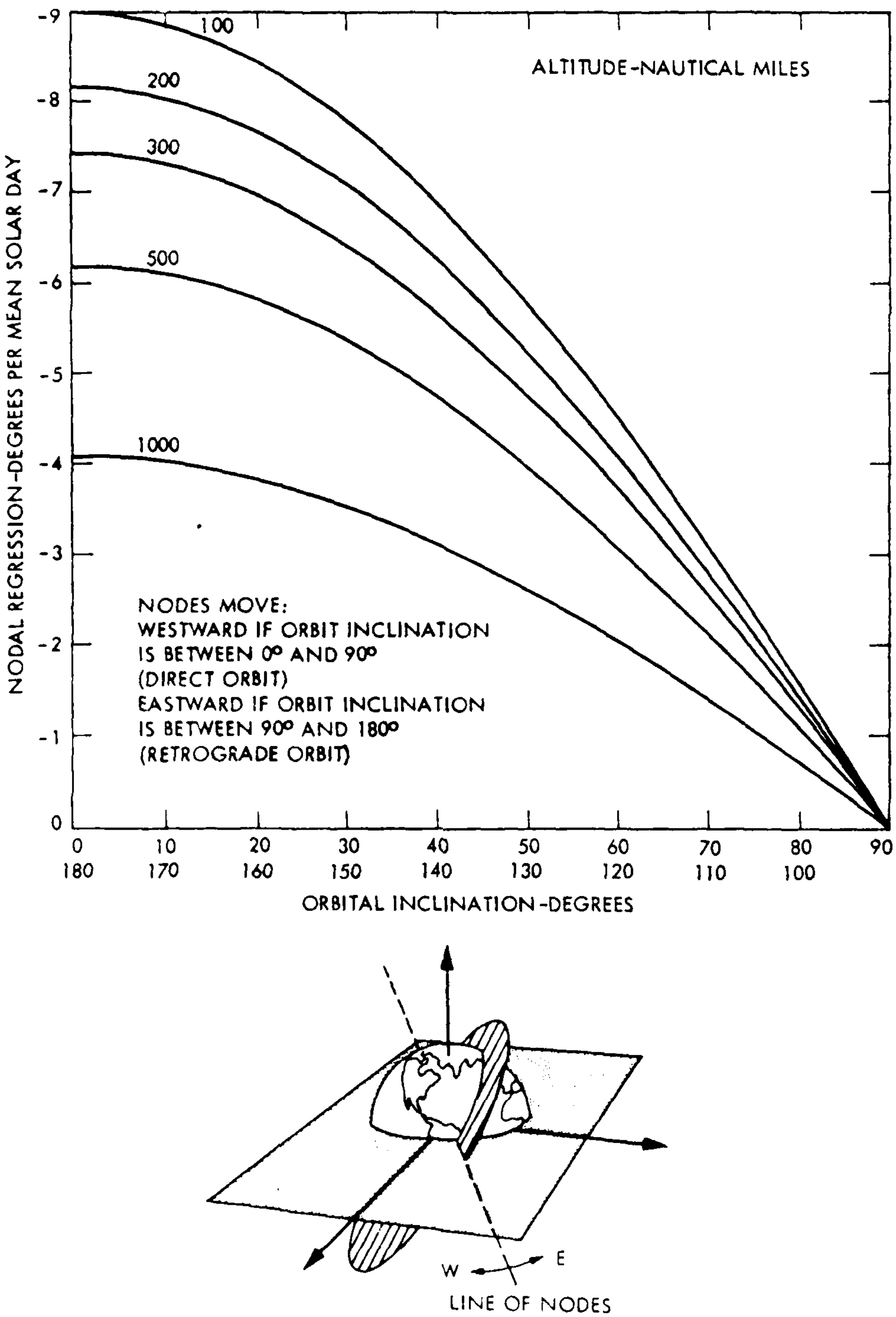


Figure 3-4. Nodal regression

3.1.2 On-Orbit Trajectory

The on-orbit trajectory of the IMPS spacecraft would be determined by the orbital injection parameters. Since the thrusters on the carrier are used only for attitude and not for translational control, and the Shuttle Orbiter would perform a backaway maneuver after the IMPS spacecraft separated from it, the orbit would stay the same for the length of the mission unless the Shuttle performed any orbit maneuvers prior to separating from or re-attaching to the IMPS spacecraft.

3.1.3 Deployment Separation Maneuver Trajectory

The deployment separation maneuver trajectory after the IMPS separates from the Shuttle should be designed to gain a safe distance between the IMPS and Shuttle Orbiter to minimize the possibility of collision. The separation trajectory design should also minimize plume impingement contamination of the IMPS by the Shuttle reaction control system.

3.1.4 Retrieval Maneuver Trajectory

The retrieval maneuver trajectory to recover the IMPS and restow it in the Shuttle cargo bay should be designed so that the relative translation and rotation rates of the grapple fixture on the carrier are within the limits of the Shuttle Orbiter remote manipulator system (RMS). The retrieval maneuver trajectory should also be designed to minimize the possibility of collision between the IMPS and the Shuttle, and to minimize the Shuttle reaction control system against plume impingement contamination on the IMPS.

3.2 MISSION SEQUENCE

The objective of sequence design is to develop a sequence that will meet as many of the IMPS mission objectives as possible, within the payload and STS mission, hardware design, and operational constraints.

3.2.1 Daylight/Darkness Windows

The duration of the daylight/darkness periods will be determined according to the period in which the launch actually occurs, and according to the orbital injections parameters. The sequence in which daylight/darkness windows occur will be determined by whether the launch happens during daylight or darkness.

3.2.2 Communications Coverage Windows

The launch window and orbital injection parameters will determine the sequence and duration of communication links available to the Shuttle Orbiter via the Tracking and Data Relay Satellite System (TDRSS) and the Spaceflight Tracking and Data Network (STDN) system. Shuttle Orbiter communications via the TDRSS utilize the Shuttle S-band phase modulation (PM) and Ku-band systems, while communications via the STDN system utilize only the Shuttle S-band PM system. The Shuttle Orbiter Ku-band system utilizes a deployable antenna and can only be used when the cargo bay doors are open and when the Shuttle is in specific attitudes. The Ku-band communication system is a combined system with the rendezvous radar and cannot be used in the radar and communications modes at the same time. The Ku-band rendezvous radar system would be used to obtain state vector information on the IMPS spacecraft relative to the Shuttle and during deployment and retrieval operations.

While the IMPS is attached to the Shuttle, payload telemetry and commands will be through hardlines to the Shuttle Orbiter payload signal processor and payload data interleaver. After the IMPS is deployed, telemetry and commands will be through RF link with the Shuttle payload interrogator.

3.2.3 Attitude Sequence Requirements

Portions of the mission will require specific Shuttle and IMPS spacecraft attitudes to fulfill the IMPS science requirements, and requirements for thermal environment and communications coverage.

While the IMPS is attached to the Shuttle, the Shuttle must be oriented in specific attitudes during portions of the mission to maintain an acceptable thermal condition. The attitudes required depend upon the beta angle, defined as the angle between the orbit plane and a line between the centers of the Earth and Sun. The beta angle is a function of the orbit inclination and the time of year of the launch. The Shuttle requires different thermal attitudes for beta angles above and below 60 degrees. For orbits with an inclination greater than 83.5 degrees, the beta angle is always greater than 60 degrees.

The Shuttle will normally be oriented in a passive thermal control (PTC) attitude, which is defined as X-axis perpendicular to the solar vector and rolling about X-axis at a rate of two to five rev/hr with multiple allowable excursions of solar viewing (+Z solar), deep space viewing (+Z space), or Earth viewing (+ZLV) as shown in Table 3-1. The Shuttle Orbiter coordinate system is shown in Figure 3-5. Table 3-1 specifies the payload recovery times for these excursions, so that repeat of the required attitudes can be planned.

TABLE 3-1. BETA ANGLE GREATER THAN 60 DEGREES

Attitude	Required Time	Payload Recovery Time at PTC
+PTC	Continuous	N/A
+ZLV	6 hr (followed by 3 hr PTC)	TBD
+Z Solar	30 min	TBD
+Z Space	90 min	TBD

Communications with IMPS instruments from the payload operations control center to the Shuttle can be in any attitude for communications via the Shuttle S-band PM system; communications via the Ku-band system require specific Shuttle attitudes so that the deployable Ku-band antenna has a view of a TDRSS. During deployed operations, use of the Ku-band radar system will require a Shuttle attitude which has the IMPS spacecraft within the field of

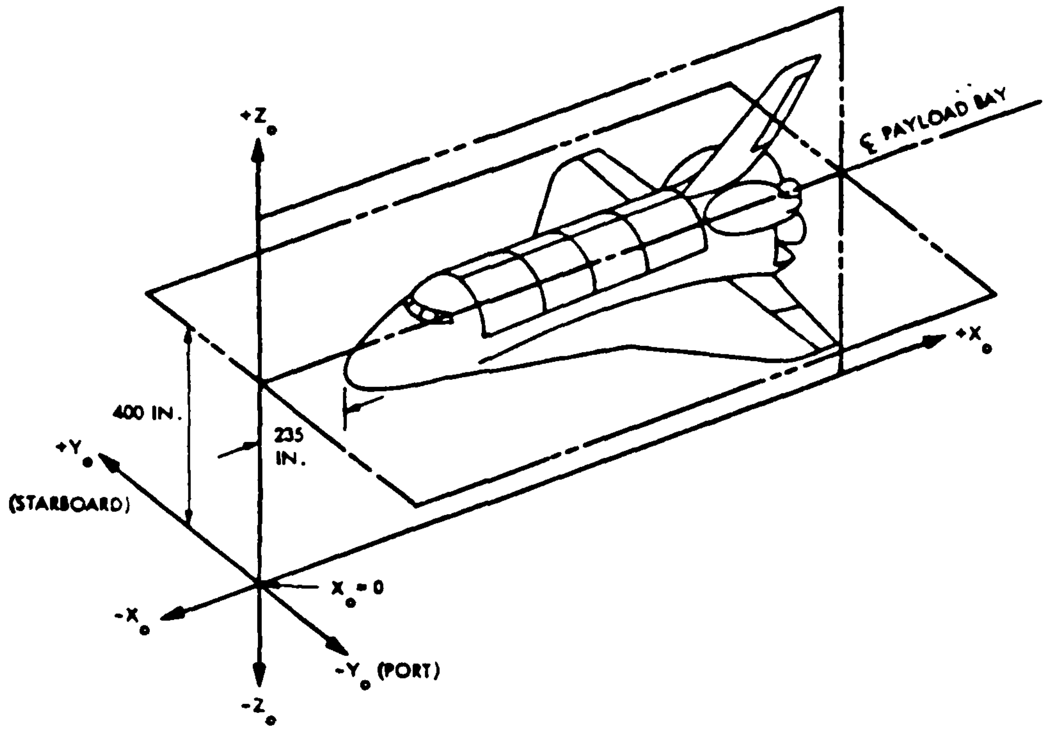


Figure 3-5. Shuttle orbiter coordinate system

Origin: In the Orbiter plane of symmetry, 400 inches below the center line of the payload bay, and at Orbiter X station = 0.

Orientation: The X_o axis is in the vehicle plane of symmetry parallel to, and 400 inches below, the payload bay centerline. Positive sense is from the nose of the vehicle toward the tail.

The Z_o axis is in the vehicle plane of symmetry perpendicular to the X_o axis positive upward in landing attitude.

The Y_o axis completes a right-handed system.

Characteristics: Rotating right-handed cartesian.
The standard subscript is 0 (e.g., X_o).

view of the Ku-band antenna. The Shuttle Orbiter requires specific attitudes to be able to send commands to, and receive telemetry from, the IMPS via the Shuttle payload interrogator (PI), because the PI antenna has a beam width bound by an 80 degree cone aligned with the Shuttle Orbiter +Z axis. The deployment separation maneuver and any subsequent Shuttle Orbiter maneuvers will determine the relative position of IMPS with respect to the Shuttle; this will determine the required Shuttle attitude for communications.

The major attitude requirements for the IMPS science instruments during deployed operations are to place the science instruments into the ram or wake of the Shuttle, and for an attitude which orients the solar array so that it is facing the Sun for the portion of the orbit that is in daylight.

3.2.4 Crew Activity Sequence Requirements

During mission operations, the crew will power up and down, execute deployment and retrieval operations, and orient the Shuttle to the attitudes required for communications and ranging.

3.2.5 Deployment Separation and Retrieval Maneuver Sequencing

The duration of the deployment and retrieval maneuver sequences will be dependent on the relative trajectories used for these maneuvers.

3.2.6 Mission Event Sequencing

After basic time-lines are established that account for the daylight/darkness and communications coverage windows, attitude and crew activity sequence requirements, and deployment and retrieval sequences, the individual IMPS spacecraft and science instrument events would be scheduled within the given time-lines. Typical events would include turning instruments and tape recorders on and off, switching operating modes of those instruments that require it, issuing commands, and doing telemetry data dumps.

3.3 CONSUMABLES ANALYSIS

3.3.1 Propulsive Consumables

The propulsive consumables include propellants required for Shuttle Orbiter orbital injection, on-orbit translational and attitude maneuvers, and IMPS attitude maneuvers.

Shuttle Orbiter:

NASA will be responsible for performing an analysis to determine the Shuttle Orbiter propellant required to achieve the desired orbital injection parameters, for deployment and retrieval translational maneuvers, on-orbit attitude maneuvers, and the de-orbit burn. This analysis will be the basis for Shuttle propellant loading.

IMPS Spacecraft:

One of the limiting factors on the time the IMPS can be in the deployed mode is the nitrogen cold gas used for attitude control. The maximum impulse of the nitrogen system is about 4400 Newton-sec.

3.3.2 Nonpropulsive Consumables

NASA will be responsible for performing an analysis to determine the required amount of Shuttle Orbiter nonpropulsive consumables such as environment control and life support system consumables.

3.4 NAVIGATION SYSTEM

The most important navigational objective during the deployed phase of the mission is for the IMPS spacecraft to know its relative position with respect to the Shuttle Orbiter. The Shuttle Orbiter Ku-band radar system could be used periodically to provide range information. Ground and space tracking and orbit determination processing, which are uplinked to the Shuttle Orbiter

general purpose computer, could be provided to the payload during attached operations and to the payload operations control center during both deployed and attached operations, and would provide Shuttle Orbiter position, velocity, attitude, and attitude rate information.

An alternate method would be to include satellite navigation system receivers on the IMPS that would give inertial position information in real-time. In conjunction with Shuttle Orbiter position information, the position of the IMPS, relative to the Shuttle, could be reconstructed in real-time in the payload operations control center.

SECTION 4

SPACE SYSTEM

Knowledge of the space system is an essential precondition for supporting the operations of the IMPS instruments system. Space system knowledge includes the following:

1) Understanding the impact of instrument selection on the IMPS subsatellite and Shuttle equipment

2) Planning instrument operations as well as data retrieval and validation for both ground and in-flight operations

3) Allocating instrument interface resources and controlling interfaces of IMPS.

Section 4 contains the following subsections:

4.1 IMPS-1: Baseline
4.2 Instrument Integration
4.3 Flight Data System - Upgrade
4.4 Ground Data System - Upgrade

Subsection 4.1 describes the space system elements configured in the first flight of the IMPS (IMPS-1) using a subsatellite with modifications. Subsection 4.2 discusses an instrument integration strategy whose objectives are to minimize incompatibilities that can occur during instrument integration onto the subsatellite. Subsection 4.3 and 4.4 focus on potential enhancements to IMPS flight and ground data systems.

4.1 IMPS-1: BASELINE

The IMPS-1 is the projected first flight of the IMPS mission series of flights. Several space system components of the IMPS-1 are identified below:

1) System Design
2) Information System
3) Subsatellite
4) Bay-Mounted Instruments
5) The Shuttle - Launch Vehicle Integration
6) The Payload Operations Control Center

This Section is devoted to descriptive overviews of the components listed above. A detailed discussion of the IMPS instruments interfaces with these components is contained in the IMPS Engineering/Science Interface Control Document (EICD), an internal JPL document available on request to government organizations. The table of contents in this document is included in this report as Appendix A.

4.1.1 System Design

IMPS instruments will be mounted onto a subsatellite or a Bridge Payload Carrier (BPC) in the Shuttle bay. Refer to Figure 4-1 for a representation of the basic Space System, with its forward and aft sides shown

The space system also includes a cable duct with cabling and two separation connector receptacles for interfacing with the STS cable system, a grapple fitting for handling by the remote manipulator system (RMS), and scuff plates, guides, and lights for rendezvous and re-attachment to the STS orbiter after on-orbit operation.

The RMS grapple fitting occupies one of six panels on the top (+z) side of the truss, leaving five top panels and two forward panels for instruments. Five of the six panels on the aft (weak) side are also available for mounting instruments and lightweight sensors.

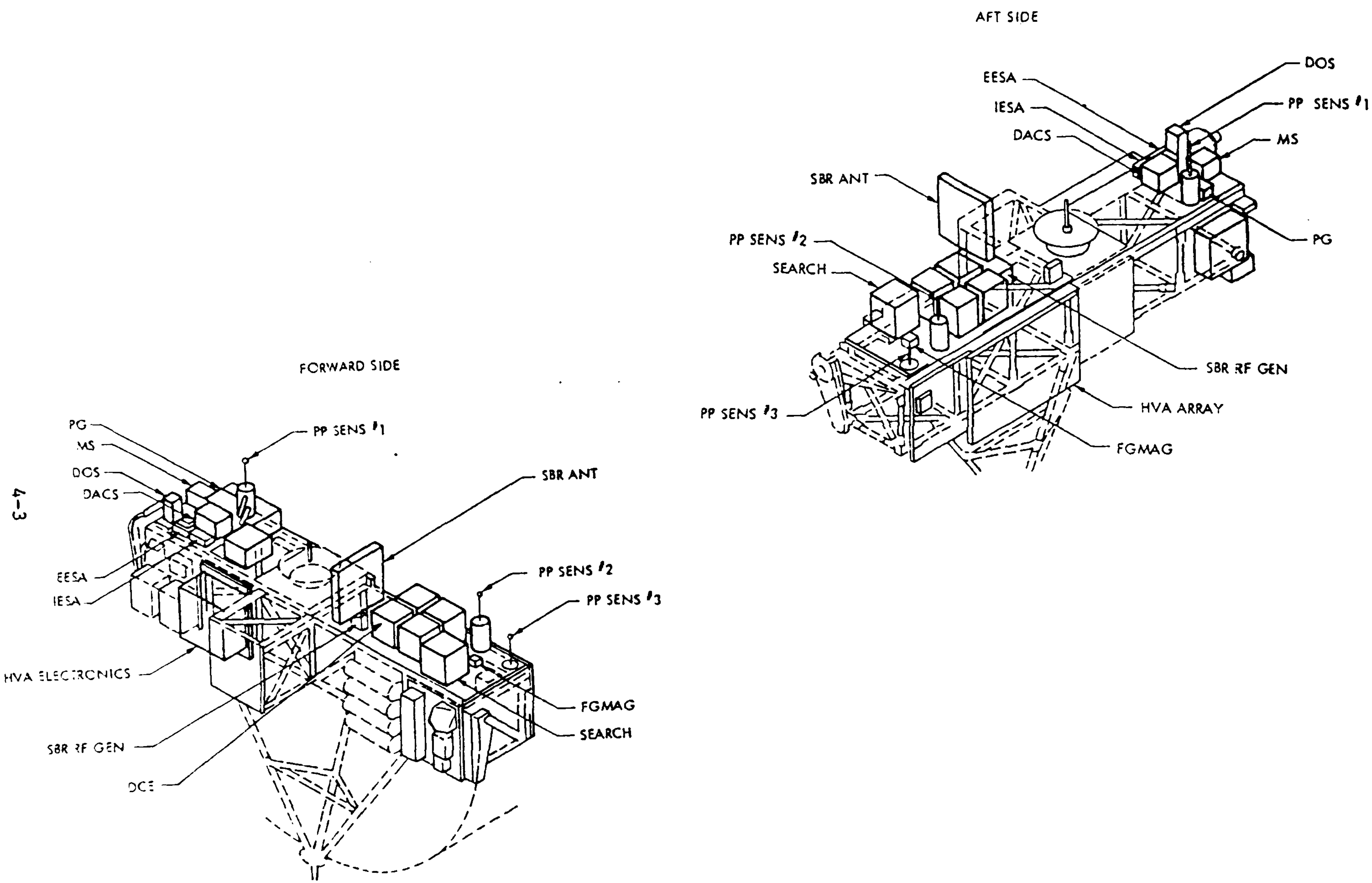


Figure 4-1. Basic Space System

Figure 4-2 shows two views of IMPS external configuration, including the IMPS-1 science instrument set overlayed onto the subsatellite. The IMPS-1 science instruments are designed to perform four auroral environment investigations, and to measure interaction within the space environment in-situ.

Seven instruments are intended for the Environment and Interactions Monitor (EIM) investigation. They are mounted on two panels located at opposite ends of the top surface of the subsatellite, in order to provide maximum separation for the two sensors of the plasma probe (PP). Two electrostatic analyzers (IESA and EESA) "look" toward +z to see Local Zenith when in the free-flying mode or when the STS is flying "cargo bay up". The Mass Spectrometer (MS) and Pressure Gauge (PG) are pointed toward +x to see ram when the IMPS is in free-flight mode. These two instruments are not designed to function while inside the cargo bay. The IESA, the EESA, the MS and the PG, together with an EIM data system, are located on one top mounting panel on the starboard end of subsatellite.

The remaining three instruments of EIM, the magnetometer (MAG), the search coil magnetometer (SEARCH) and the PP, point toward +z and will be in ram when STS is flying "cargo bay forward". These instruments are mounted on a top mounting panel on the port end of subsatellite.

The space-based radar (SBR) sample antenna is mounted on a panel in the x-z plane on the top of the subsatellite. The antenna has its edge to ram while in and out of the cargo bay.

The photovoltaic array space power (PASP) extends to two panel areas on the aft (+x) side of the subsatellite to provide ram and as maximum sunpointing when IMPS-1 is in the free-flight mode. RASP is not designed to function inside the cargo bay.

The optical effects monitor (OEM) and the dielectric materials experiment (DME) are mounted on top of the subsatellite pointed toward +z. They will be pointed in ram when the STS is flying "cargo bay forward".

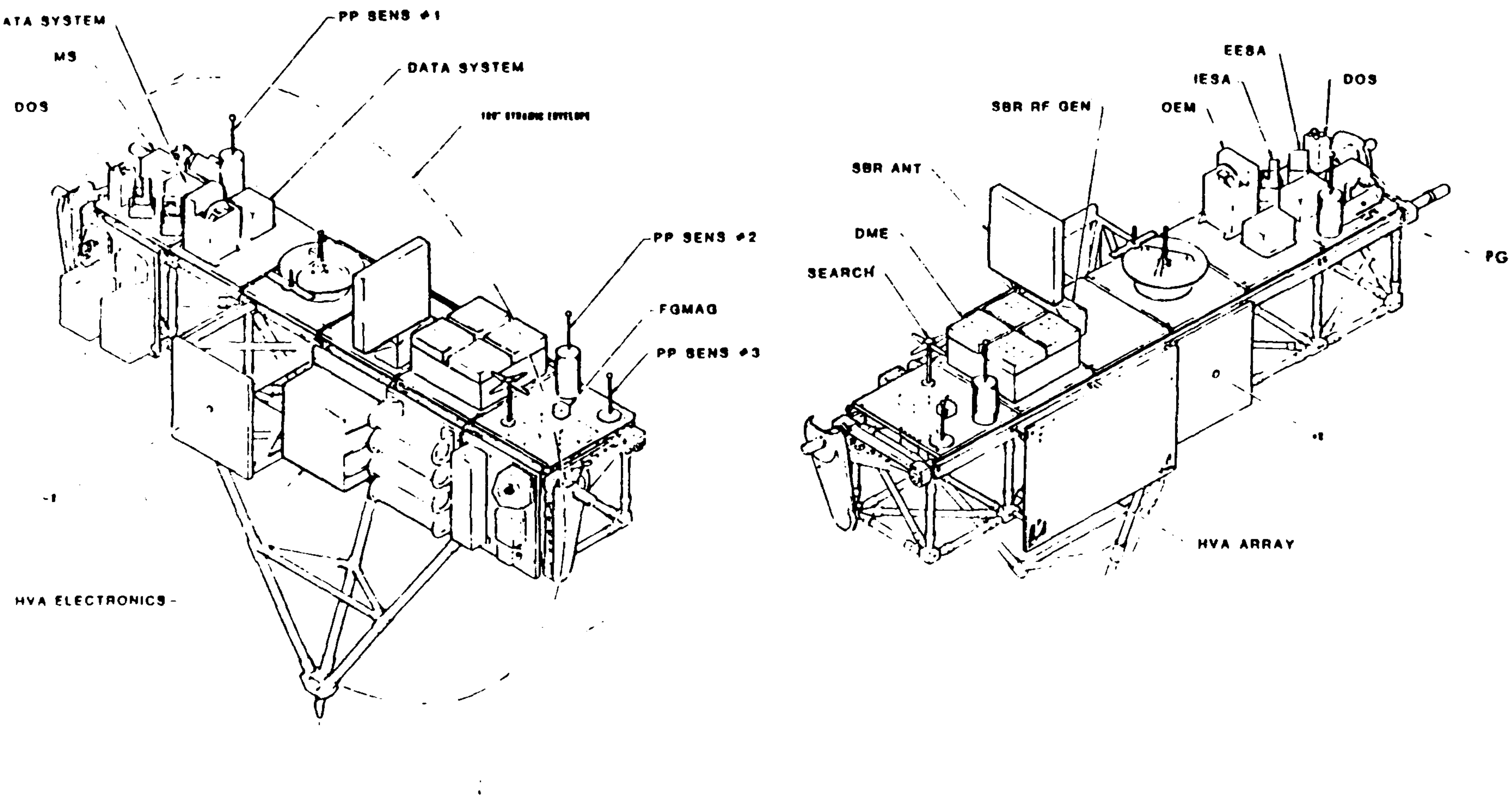


Figure 4-2. IMPS-1 configuration

Figure 4-3 presents the remote instruments configuration, showing the Space Irradiated Integrated Optics (SIIO) mounted inside the STS cargo bay and attached to a bridge payload carrier (BPC). The SIIO's located in any one of 13 locations on either side of the cargo bay.

IMPS-1 Internal Functional Relationship

The functional relationship between engineering subsystems and the instrument payload is represented as a block diagram in Figure 4-4. The IMPS engineering subsystems and instruments are mounted on both the subsatellite and in the Shuttle bay.

IMPS-1 Mass and Power Estimates

Instrument mass and power estimates for the IMPS subsystems and instruments are detailed in Tables 4-1 through 4-3. As a first order figure of merit for Shuttle flights, a relationship of weight versus length can be plotted as shown in Figure 4-5. Payloads above the "optimum payload line" are considered weight-intensive for the Shuttle, and those below the line, are length intensive. Assuming that bay-mounted instruments (attached to bridge beams along the sill of the bay) could share space with other Shuttle payloads, the subsatellite can then be considered. It is expected that mass will grow at a faster rate than length. The plot in Figure 4-5 represents an oversimplification of the Shuttle resource equation which also includes: Tape Recorder (T/R) usage, command requirements, telemetry rates, use of Shuttle expendables (e.g. oxygen, propellant), orbital altitude, requirements for a mission specialist, and ancillary data.

4.1.2 Bay-Mounted Instruments

Figure 4-3 shows the Space Irradiated Integrated Optics (SIIO) instrument mounted to the bridge payload carrier (BPC), which can be located in selected locations on either side of the cargo bay with STS services connected directly to it, depending on the location selected.

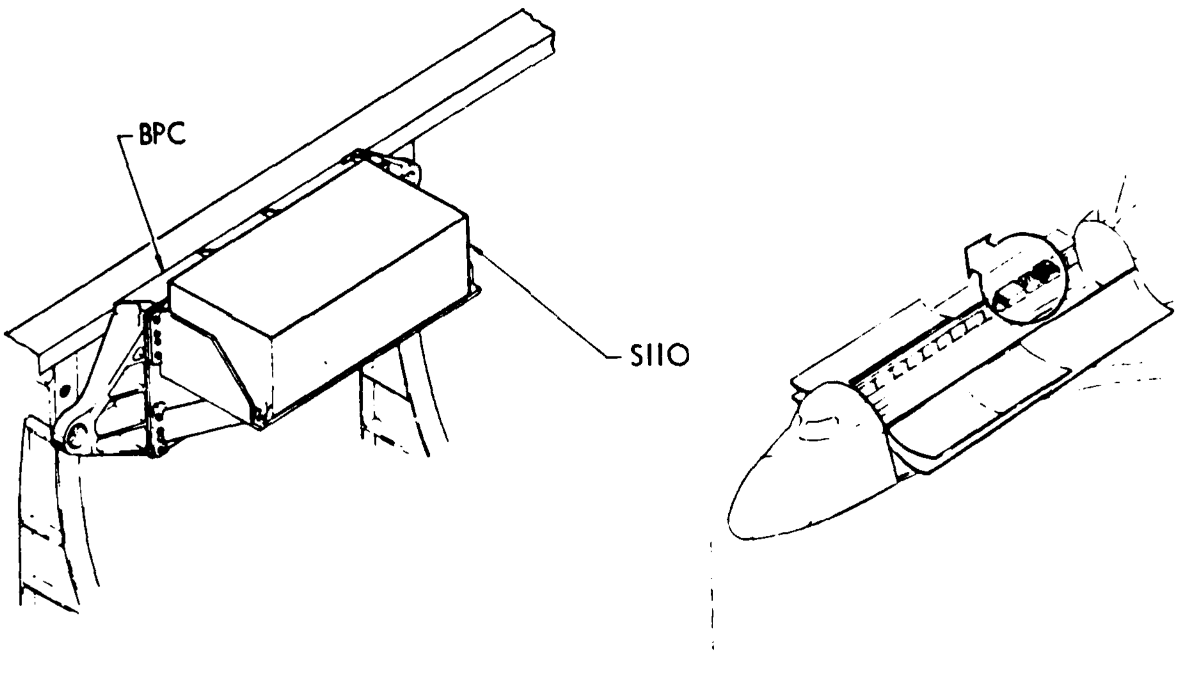


Figure 4-3. Remote instruments configuration

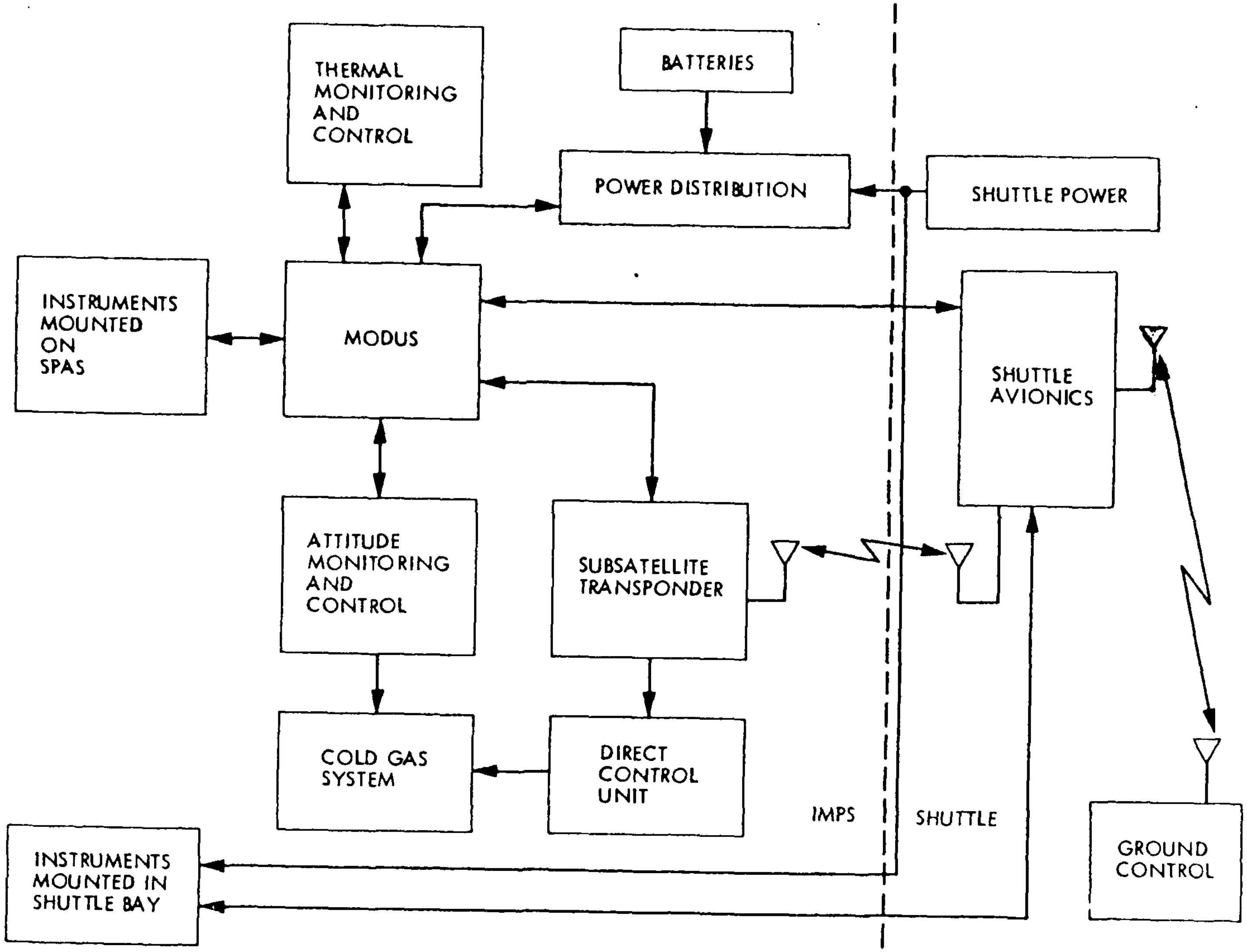


Figure 4-4. IMPS functional block diagram

TABLE 4-1. Mass and Power of IMPS Instruments*

Instrument	Total Mass (kg)		Normal Power (W)	
EIM:				
Electrostatic Analyzer (ion)	1.86		2.60	
Electrostatic Analyzer (Electron)	1.86		2.60	
Plasma Probe	2.61		9.50	
remote sensor	0.68			
"	0.68			
"	0.68			
Pressure Gauge	1.70		5.60	
	5.40			
Mass Spectrometer	13.60		30.00	
Fluxgate Magnetometer	1.50		2.00	
	0.50			
Search Coil Magnetometer	1.50		2.00	
	2.00			
Data System	7.30		18.00	
TOTAL, EIM		41.87		72.30
PASP		60.00		25.00
SBR		10.00		0
DME		50.00		50.00
SBL:				
Optical Effects Module	7.50		4.00	
Structural Materials Degradation	47.40		20.00*	
Advanced Angular Sensor	1.25		20.00*	
Data System	7.30		18.00	
SIIO (Shuttle Bay)	(50.00)		(28.34)	
TOTAL, SBL		63.45		62.00
TOTALS FOR ALL INSTRUMENTS		225.32		209.30

* Conservative estimates.

TABLE 4-2. Mass and Power Estimate: Attached Mode

	Mass (kg)		Power (W)	
Subsatellite, Attached Mode				
Electrical System	88		190	
Mechanical System	444		0	
Instruments	225		209	
Total - Subsatellite		757		399
Bay-Mounted				
Instruments	50		28	
Mechanical System	68		0	
Total - Bay-Mounted		118		28
Totals of all resources used		875		427
SHUTTLE CAPABILITY (1/4)		2721		520

TABLE 4-3. Mass and Power Estimate : Free-Flight Mode

	Mass (kg)	Power (W)
Subsatellite, Free-Flight Mode		
Electrical System (Normal Mode)	88	261
Mechanical System	444	0
Instruments	225	209
Total - Subsatellite	788	470

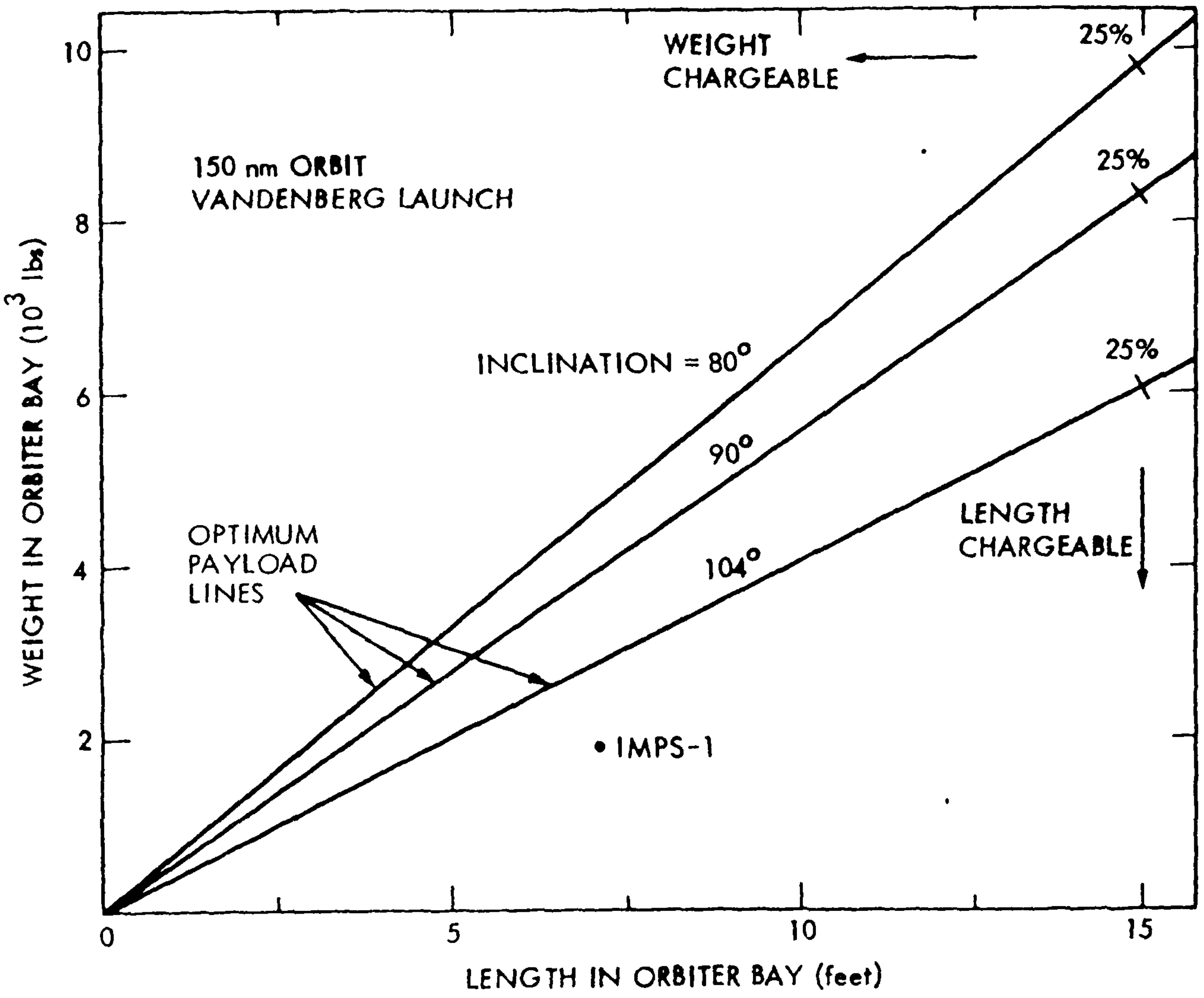


Figure 4-5. Shuttle resources as weight and length

Since the STS provides only four power points located on the port side of the cargo bay, and four data points located on the starboard side of the cargo bay, it is difficult for small side-mounted instruments to obtain both of these services from the STS. As in Figure 4-3 shown, the SIIO is mounted on the port side. This mounting location assumes the use of STS-provided power and instrument internal data storage with no data iterface to the subsatellite or the STS. Power on/off capability from the STS is a requirement. An optional configuration is to mount the SIIO instrument on the starboard side. Here it can connect through Standard Mixed Cargo Harness (SMCH) cables to the STS data system and obtain power via a Power Accomodation Terminal (PAT) and extender cables across the cargo bay.

4.1.3 Information System

The information system handles data transmission and retrieval between the instruments and the Payload Operations Control Center (POCC). In the case of IMPS, the location of the Payload Operations Control Center has not yet been determined. Figure 4-6 shows the facilities making up support operations based at the STC and the various communication paths that can exist between the Shuttle Orbiter and other control facilities. Operations at JSC will serve as a subset of this information system and their role is included in subsequent discussions of the uplink (telecommand) and downlink (telemetry) segments of the information system.

Uplink (Telecommand):

A block diagram representing the flow of telecommands is shown in Figure 4-7. It is included in this report to provide a better understanding of the system to JPL and AFGL personnel involved in IMPS instruments development and their integration onto the subsatellite.

1) Sources of Command

Commands to the IMPS payload may be issued from the IMPS POCC, from JSC, and from the mission specialist using the Aft Flight Deck (AFD) keyboard aboard the Shuttle Orbiter.

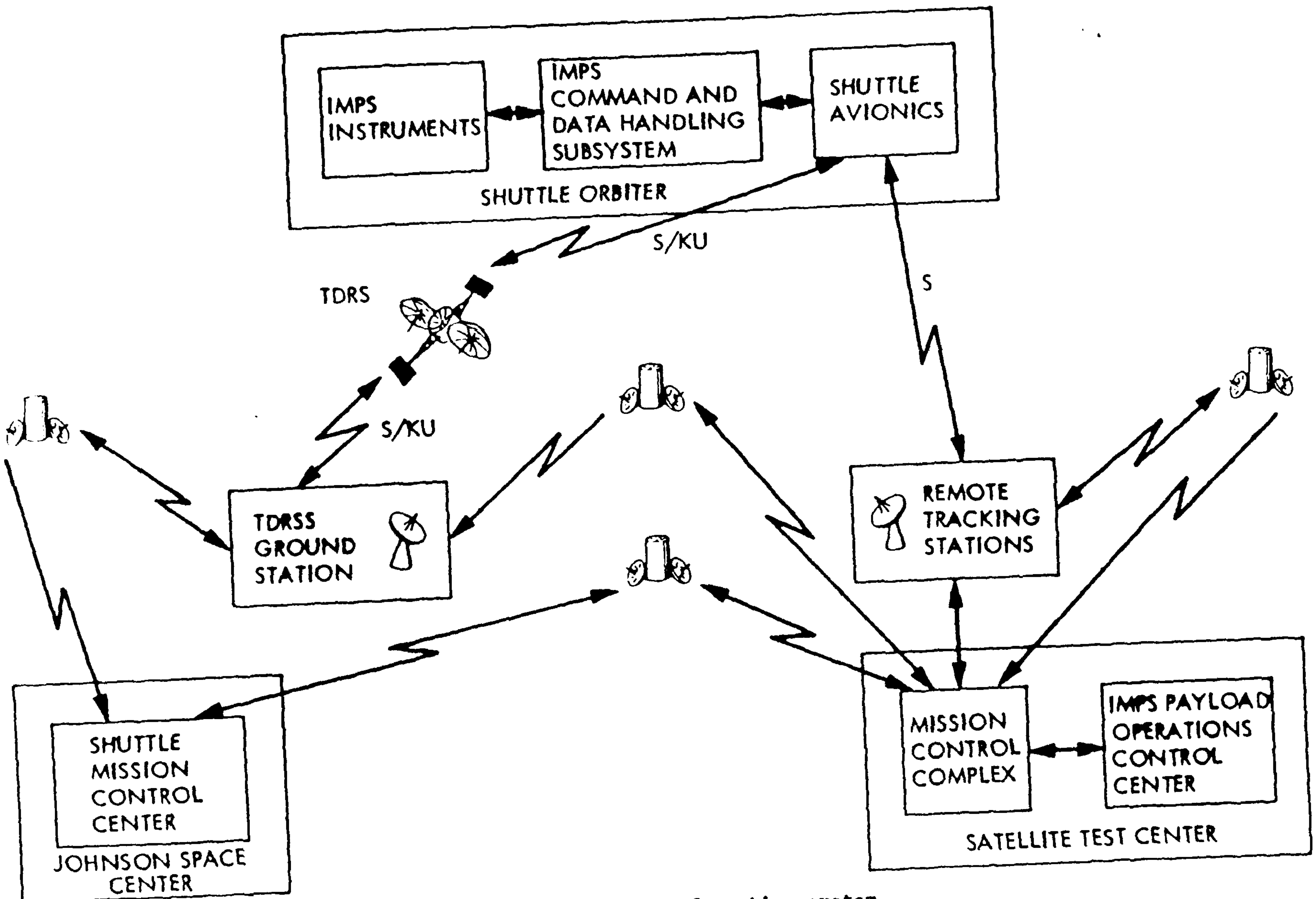


Figure 4-6. Information system

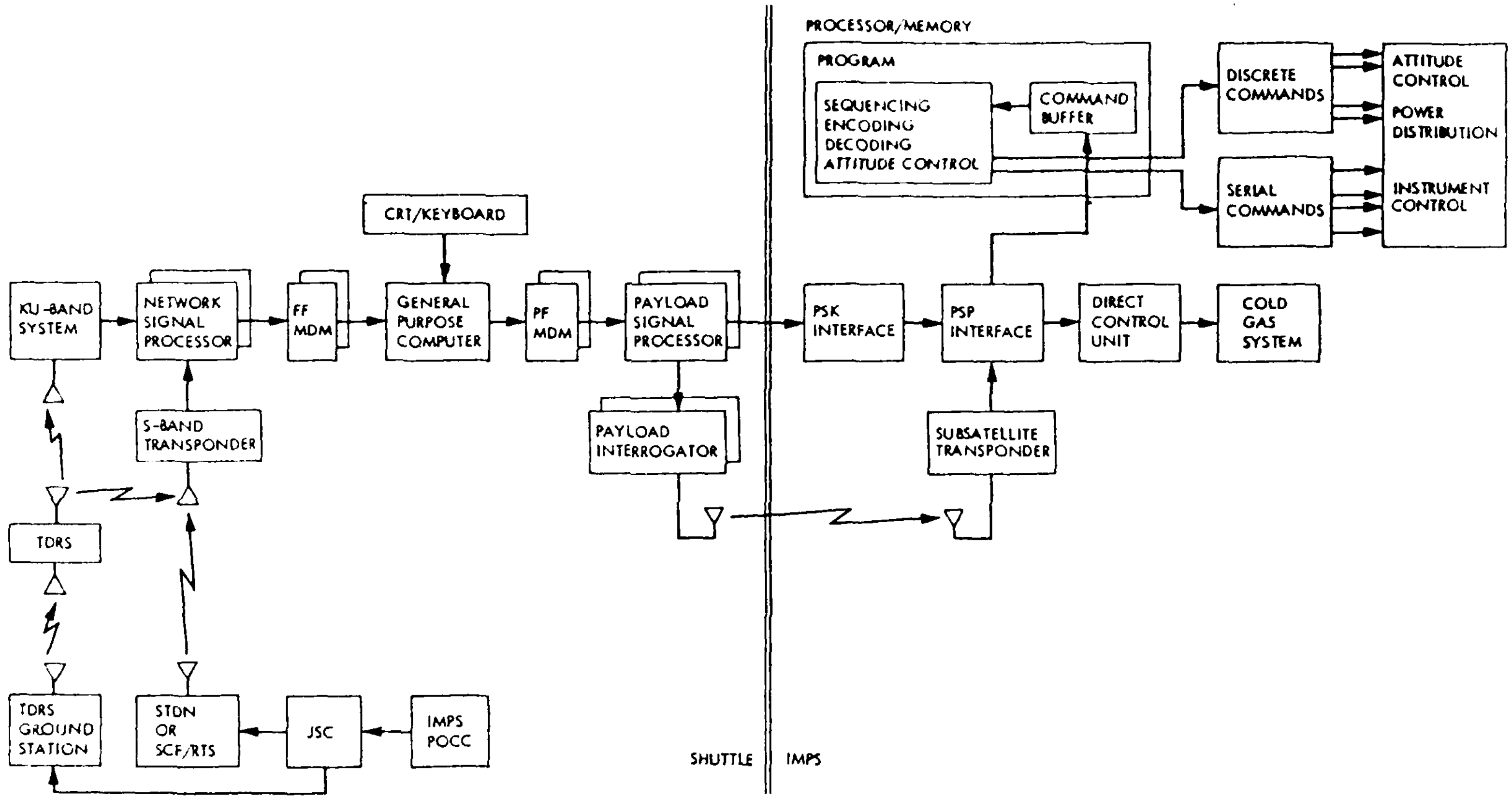


Figure 4-7. Block Diagram of Uplink Telecommand Flow

2) Ground to Ground

The IMPS POCC and JSC are linked to each other and to the Tracking and Data Relay Satellite (TDRS), SCF/RTS, and Spaceflight Tracking and Data Network (STDN) ground stations by a network of domestic satellite links and ground lines.

3) Ground to Shuttle

There are three ways to transmit information from the ground to the Shuttle:

1. The S-band PM (phase modulation) from a STDN or SCF/RTS ground station directly to the Shuttle (maximum command rate = 512 bps)

2. The S-band PM from a TDRSS ground station to TDRS to the Shuttle (maximum command rate = 512 bps)

3. The Ku-band from a TDRSS ground station to TDRS to the Shuttle (maximum command rate = 128 kbps)

4) Aboard the Shuttle

Signals from the Ku-band and S-band transponders pass through the network signal processor, then through a full-frequency demodulator into the General Purpose Computer (GPC). Commands issued by the Shuttle astronauts from the AFD keyboard also enter the GPC. The GPC sends the commands intended for the IMPS through a partial-frequency modulator to the payload signal processor.

5) Shuttle to IMPS

The Shuttle communicates with the IMPS by cable (in attached mode) or by radio link (in free-flyer mode).

ATTACHED MODE. In attached mode, the commands pass from the Payload Signal Processor (PSP) over a cable to the PSK interface on the IMPS, and into the Payload Signal Processor Interface (PSPIF).

FREE-FLYER MODE. In free-flyer mode, commands from the orbiter PSP pass through the payload interrogator and are transmitted by S-band to the subsatellite transponder. From the transponder they pass to the PSP interface within the IMPS Data Handling Subsystem (DHS).

6) Within the MODUS

The PSPIF monitors the signals received from the Shuttle avionics. It detects the valid 48-bit command words and stores the actual commands (in the form of 8-bit words) in the IMPS command buffer. It reports an error if an incorrect command is received by setting a flag in the status data portion of the IMPS telemetry frame. The MODUS reads the command buffer and sequences all of the IMPS instrument events.

7) MODUS to IMPS Instrument

The MODUS issues two types of commands to the IMPS instruments:

DISCRETE COMMANDS. Discrete commands are sent to the IMPS instruments on a dedicated line in the form of a switch closure between the dedicated line and the DHS signal ground. The commands are pulses of 32 m-sec length.

SERIAL COMMANDS. The MODUS can transfer a 16-bit data word on a dedicated clock and data line to the user. The maximum word rate on any single serial command line is 1 word/sec.

Downlink (Telemetry):

A block diagram representing the data flow from the IMPS instruments to the IMPS POCC is shown in Figure 4-8. It is included here to provide a better understanding of the system to JPL and AFGL personnel involved in IMPS instrument development and their integration onto the subsatellite.

1) Instruments to MODUS

The MODUS collects three types of information from the IMPS instruments: serial data, analog status, and discrete status.

SERIAL DATA. Serial data from the IMPS instruments are stored in a set of 32 x 16-bit word, first-in-first-out (FIFO) buffers, one buffer per instrument. When one of these serial data buffers becomes half full, i.e. contains more than 16 words of data, it raises a signal to the processor. In response to this half full signal, the processor transfers data out of the buffer in 15-word blocks to the science data portion of the telemetry frame in RAM. It then affixes a one word instrument ID to the data. Therefore, each data package from an IMPS instrument occupies 16 words of the telemetry frames. If a serial data buffer overflows, it completely resets itself and raises an error signal to the processor; at which time, all the data in the buffer are lost.

ANALOG STATUS. The analog status lines from the IMPS engineering and instrument systems feed into two 40-channel analog multiplexers. The signals from the multiplexers subsequently feed into an analog-to-digital converter. The processor, through software control, samples each analog line at a specified time rate, typically once per second. It stores these sample data in the status data portion of the telemetry frame.

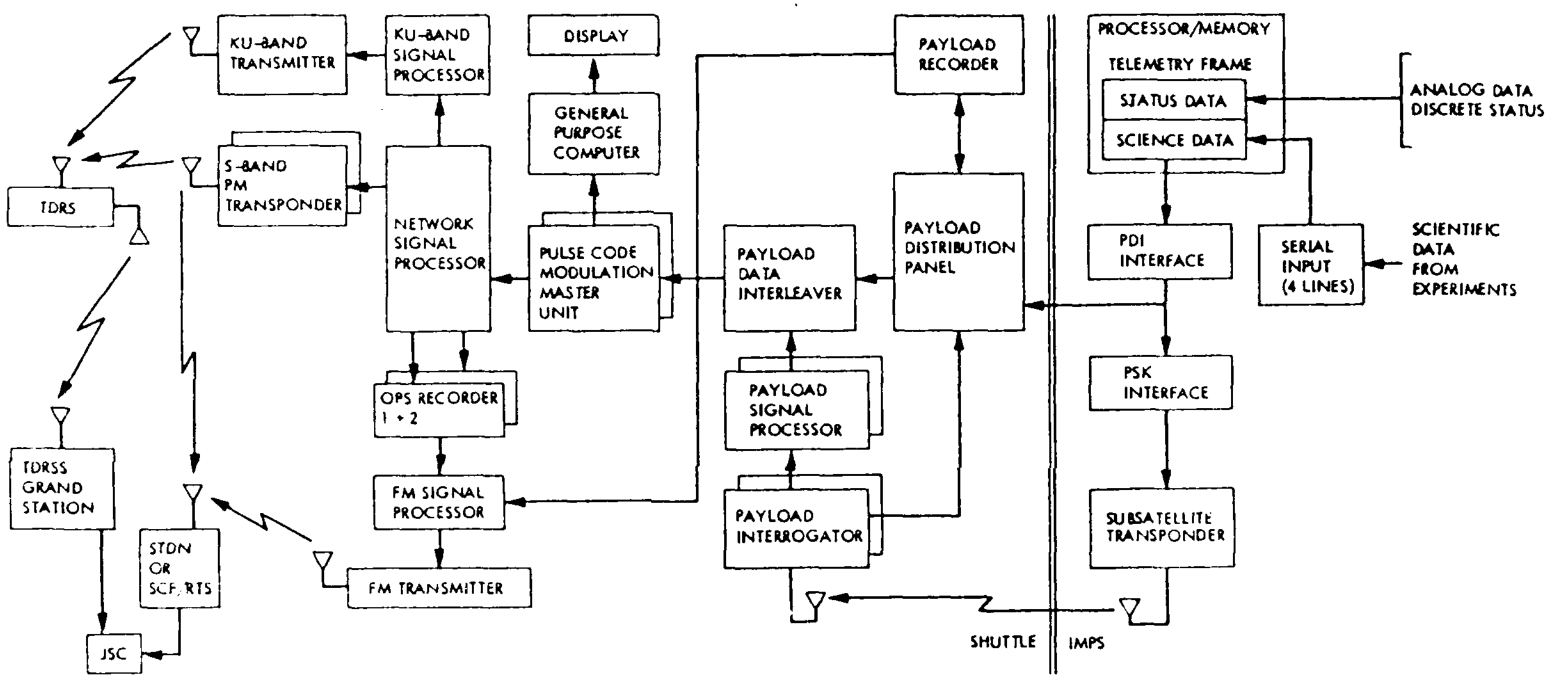


Figure 4-8. Block diagram of downlink telecommand flow

DISCRETE STATUS. The discrete (bi-level) status lines from the IMPS engineering and instrument systems lead into five discrete status modules at 16 lines per module. The processor, through software control, samples each discrete status line at a specified rate: typically, once per second. It stores this information in the status data portion of the telemetry frame.

2) Data Flow Within the MODUS

Within the MODUS, all data is stored in the telemetry frame within RAM (random access memory) and is then transmitted to the Shuttle through the PDI Interface.

TELEMETRY FRAME. The telemetry frame has a Shuttle standard frame format #1. It is formatted as a 512 x 16-bit word structure with the following characteristics,as illustrated in Figure 4-9):

1. Words 5, 9, 13, 17, . . . (every 4th word) contain an alternating bit pattern beginning with 1.

2. Words 1-128, the status data portion, contain:
   - command history
   - digital status data
   - analog status data
   - event indicators for the AFD display and the IMPS POCC.

3. Words 129-512, the science data portion, contain serial data from the IMPS science instruments. Since one quarter of these 384 words are reserved for the alternating bit pattern, there are 288 words available for instrument data. Since each data package (consisting of instrument ID and actual data) contains 16 words, there is room for 18 of these packages in each telemetry frame.

1 FRAME	2 SYNC	3 DHS TIME	4 DHS TIME	5 ABP	6 CMD HIST	7 CMD HIST	8 CMD HIST
9 ABP	10 EXP CMD HIST	11 EXP CMD HIST	12 EXP CMD HIST	13 ABP	14 EXP CMD HIST	15 EXP CMD HIST	16 S/S ERRORS
17 ABP	18 CMD WD CHECK	19 SUBSAT-ELLITE STATUS	20 SUBSAT-ELLITE STATUS	21 ABP	22 MNVR STATUS	23 MNVR STATUS	24 SPARE
121 ABP	122 SPARE	123 SPARE	124 SPARE	125 ABP	126 SPARE	127 SPARE	128 SPARE
WORDS 129-512 SCIENTIFIC DATA (RECORDED AT MCC)							

16 BITS/WORD
512 WORDS/FRAME
1 FRAME/DATA CYCLE

.9766 DATA CYCLES/SECOND

ABP - ALTERNATING BIT PATTERN

Figure 4-9. Subsatellite telemetry stream

PAYLOAD DATA INTERLEAVER INTERFACE (PDIIF). The PDI interface sends data from the MODUS to the Shuttle avionics in a continuous stream at 8 kbps. It draws this data from a 32 x 16-bit word FIFO buffer within the PDIIF. When this buffer becomes half empty (i.e. when it contains less than 16 words of data), the PDIIF raises a signal to the processor. In response to this "half empty" signal, the processor transfers a 16-word block of the telemetry frame from RAM to the PDIIF buffer. If the telemetry frame is not ready to be downloaded, the processor transfers a 16-word block of dummy data to the PDIIF buffer. In either case, the processor sends the PDIIF buffer 16 words of data to download.

3) MODUS to Shuttle

The MODUS communicates with the Shuttle Orbiter either directly by cable (in attached mode) or by radio link (in free-flyer mode).

ATTACHED MODE. In the attached mode, the IMPS payload is connected to the Shuttle Orbiter by cable. The output of the PDIIF enters the Shuttle avionics directly through a cable. The data passes through the payload distribution panel and into the payload data interleaver.

FREE-FLYER MODE. In free-flight, the payload is physically separated from the Shuttle, and the only route for telemetry and telecommand is via radio link. The output of the PDIIF passes through the PSK interface and into the IMPS transponder, which transmits the data at 8 kbps to the Shuttle antennas. On board the Shuttle, the data passes from the antennas to the payload interrogator, through the payload signal processor, and finally, to the payload data interleaver.

4) On Board the Shuttle

On board the Shuttle Orbiter, some of the status data from the IMPS telemetry frame is read by the general purpose computer and displayed on the AFD display. The IMPS data, together with all the data from other payloads and from the Shuttle systems, pass into the network signal processor and thence to the radio transponder of the Shuttle.

Shuttle to Ground

The Shuttle can transmit data to ground station facilities in four different ways:

1) Ku-band to TDRS, to TDRSS ground station (maximum at 1.025 Mbps)

2) S-band PM (phase modulation) to TDRS, to TDRSS ground station (maximum 64 at kbps)

3) S-band PM, to STDN or SCF/RTS ground station (maximum 64 kbps)

4) S-band FM (frequency-modulated), to STDN or SCF/RTS ground station

6) Ground to Ground

The TDRSS, STDN, and SCF/RTS ground stations and the GSFC, the JSC, and the IMPS POCC will be connected by a network of domestic satellite links and ground lines.

4.1.4 Shuttle - Launch Vehicle Integration

Structural/Mechanical Interfaces:

The subsatellite is capable of being located anywhere between STA 180 (X_o = 715) and STA 298 (X_o = 1175.2) in the Shuttle Orbiter cargo bay with certain operational restrictions applying to some of the locations. The subsatellite is attached to the Shuttle by two longeron trunnion fittings and one keel trunnion fitting. To enable deployment by the Shuttle RMS, the subsatellite uses an RMS grapple fixture supplied by the STS and cable separation mechanisms. Once the subsatellite has been separated, the power and control cables cannot be reconnected.

Electrical Power and Avionics Interfaces:

The subsatellite utilizes one main DC power cable which corresponds to the standard service power available for a payload that has been allocated one fourth of the cargo bay. The telemetry, command, timing, and control interface allocation in the Shuttle cargo bay are listed in Table 4-4. An orbitor to subsatellite avionics interface functional block diagram is shown in Figure 4-10. The subsatellite utilizes the Shuttle aft flight deck keyboard, CRT (Cathode Ray Tube), and standard switch panel in order to control, monitor, and operate the subsatellite.

Thermal/Environmental:

The only active thermal/environmental interface between the subsatellite and the STS consists of a purge of the Shuttle Orbiter cargo bay with air or nitrogen gas on the pad prior to lift-off.

Software Interfaces:

The subsatellite utilizes standard Orbiter general purpose computer software services from the payload data interleaver for telemetry crew display and monitoring. For command initiation the subsatellite uses the payload signal processor.

TABLE 4-4. Orbiter/Subsatellite Cargo Element Interface Allocation

Orbiter Service	Interface Type/ Description	Number of Interfaces
Payload Data Interleaver	Telemetry Inputs	1
Payload Signal Processor	Command Path Backup	1 1 (2)
Master Timing Unit (PTB)	GMT Output, Modified IRIG B MET Output	2 1
Standard Switch Panel	Panel Allocation (Sections)	1
S-Band Payload Interrogator	RF COMM/TLM Path	1 (1)
Standard Mixed Cargo Harness (SMCH)	AFD	
	RF Cable	1
	HO Cable	1
	ML Cable	1
	Cargo Bay	
	RF Cable	1
	HO Cable	1
	ML Cable	1
	O-AWG Cable	1

Notes: 1) Orbiter has a requirement for RF communications with only one detached payload at a time.

2) Only one PSP command output is active at a time.

4.1.5 Payload Operations Control Center

The subsatellite will be controlled either from JSC or from the Satellite Test Center (STC). The actual flying of the subsatellite will be performed by the mission specialist from the aft flight deck of the Orbiter. Experimental data, STS ephemeris, attitude and flight history data (e.g., thruster firings and water dumps) will be provided on computer-compatible tapes after the flight. Orbital support for the duration of the mission will also include periodic health and status checks. A mission operations approach, consistent with the project objectives and requirements, is discussed in the Ground Data System - Potential Upgrade section of this report.

4.2 INSTRUMENT INTEGRATION

4.2.1 Overview

Figure 4-11 presents a simplified Venn diagram indicating typical interfaces between science instruments, a subsatellite, and the resultant environment. For illustrative purposes, only two instruments are shown in Figures 4-11 and 4-12.

The LDEF system provides an example which approximates the concept represented in Figure 4-12 by presenting both positive and negative aspects of the isolated system approach. LDEF system design minimizes interference between the subsatellite and the instruments by limiting the common environment to the mechanical mounting and an on/off signals; interference between instruments is thereby limited to contamination (material, EMC, etc.) only. The negative aspects must also be considered.

Due to the concern over facilitating integration, a number of sacrifices have been made. For example, subsatellite self provided power has been eliminated, data storage has been more severely limited, and object pointing capabilities have been reduced. An even more serious limitation is the inability to receive in-flight science data or transmit control data allowing instrument reconfiguration. Data is received only upon completion of the flight.

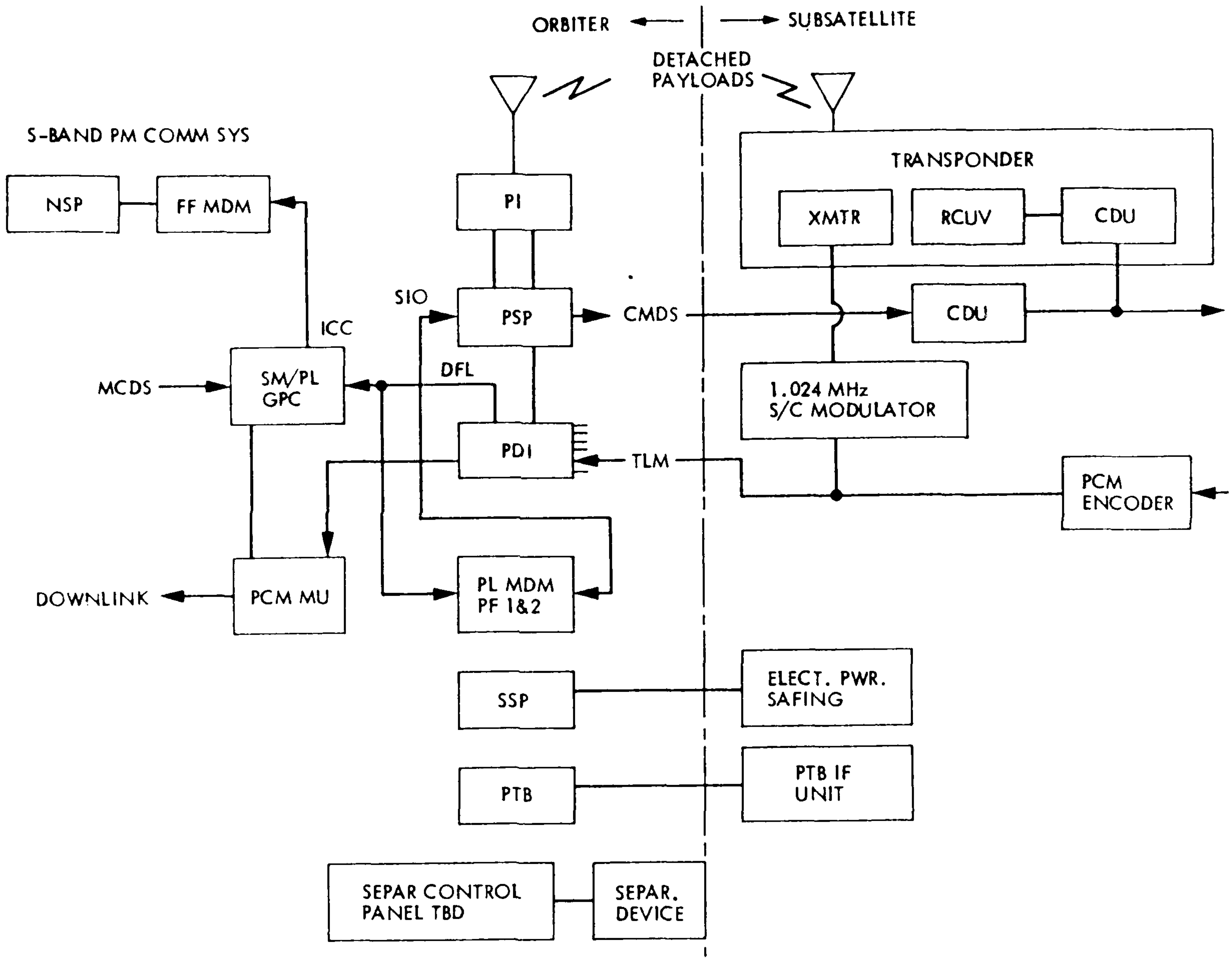


Figure 4-10. Orbiter/Subsatellite Avionics Functional Block Diagram

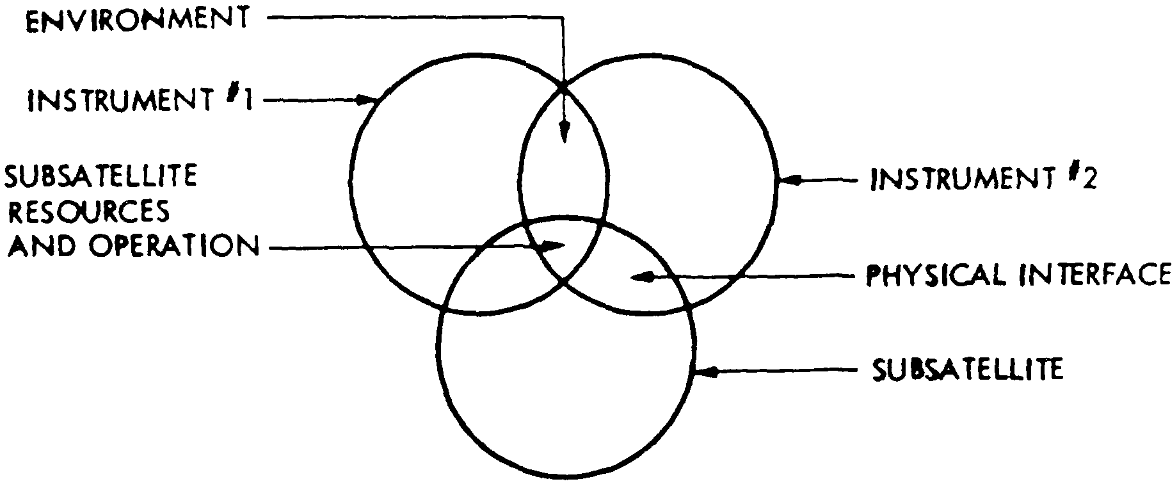


Figure 4-11. Simplified Venn Diagram of Typical Instruments and Subsatellite Environment

In an uncontrolled environment such as that shown in Figure 4-11, individual activities performed by the science instruments or by the subsatellite could possibly result in inadvertent interactions with other activities onboard the spacecraft. These unintended interactions are not confined to pre-launch activities, but could extend to post-launch activities as well.

An ideal system environment, as depicted in Figure 4-12, enables each instrument to function without concern for inadvertent interactions with other on-board activities.

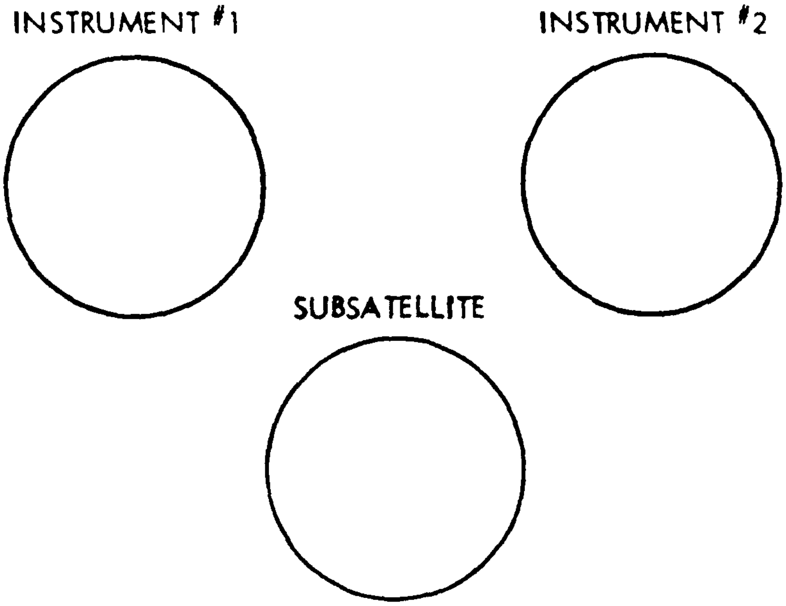


Figure 4-12. Simplified Venn Diagram Showing an Ideal Environmental System

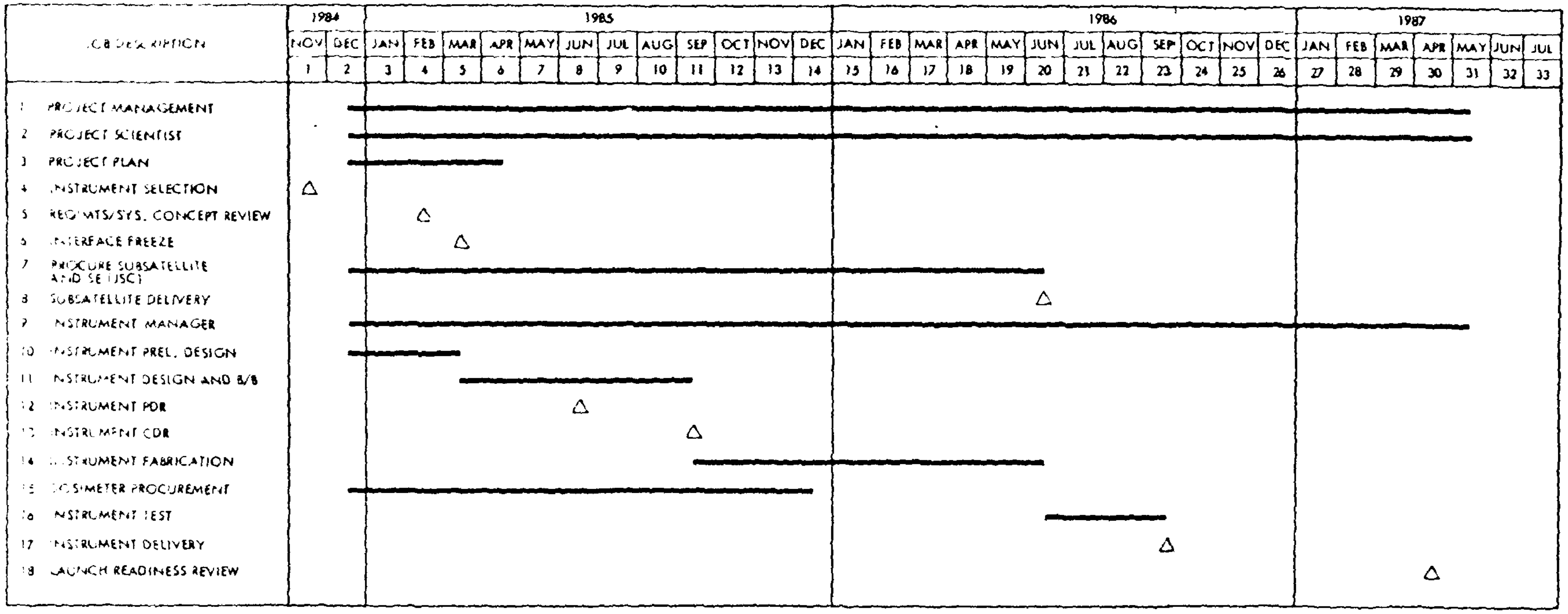
On board the subsatellite, instruments increase must be permitted so long as the increase does not interfer with other instruments. Instrument addition, deletion, and modification must be permitted, concurrently with providing a non-obtrusive environment for the existing elements. This is often difficult to implement in the multiple payload shuttle environment, but the benefit is significant in terms of the accomplishment of mission objectives and the avoidance of major cost changes and schedule delays. The following subsections expound a specific approach toward solving the problems of instrument integration.

4.2.2 IMPS Instrument Integration Approach

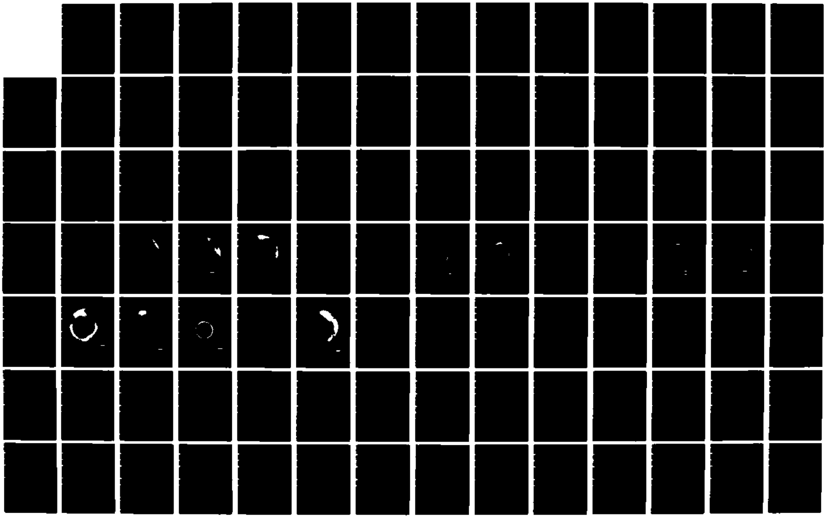
IMPS instrument integration will be completed by time of launch. Figure 4-13 provides a preliminary instrument development schedule, indicating major project milestones. Instrument integration has been realized throughout the development phase by persuing the logical progression of each instrument, leading ultimately to the integration of the subsatellite system. To effect system integration, each instrument progresses through the following phases.

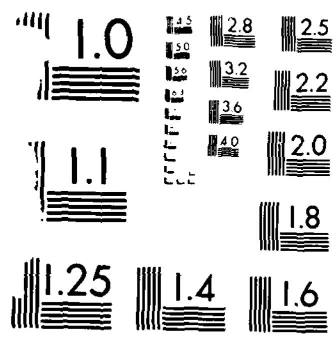
1. Definition of the external interfaces of each instrument.
2. Verification of subsatellite data handling interface.
3. Verification of subsatellite mechanical interface.
4. Satisfactory completion of environmental qualification.
5. Satisfactory completion of pre-ship review
6. Satisfactory completion of pre-launch baseline testing.

Figure 4-13. Preliminary Instrument Development Schedule



AD-A165 222 INTERACTIONS MEASUREMENT PAYLOAD FOR SHUTTLE (IMPS) 2/3
DEFINITION PHASE STUDY(U) JET PROPULSION LAB PASADENA
CA G C HILL 15 DEC 84 JPL-D-1865 AFGL-TR-85-0023
UNCLASSIFIED NAS7-918 F/G 22/2 NL





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A description of each of these phases is presented in the following subsections.

4.2.2.1 Definition of Instrument Interfacer.- During this phase, activities are concentrated on defining the interface between the instrument and its external environment. Interfaces may be categorized as either electrical, mechanical, or environmental, e.g., EMC or magnetic. Instrument interfaces are defined in and controlled by an Interface Control Document (ICD).

Each ICD is placed under configuration management two months prior to Preliminary Design Review (PDR) for the instrument; from this point, any instrument or interface modification must be accomplished through a change control process. The Change Control Board (CCB) must review and approve any changes to the baseline instrument or ICD. This practice provides a high degree of flexibility to the instrument developer, while identifying and controlling external instrument interfaces early in the project.

The data system electrical interface is based on a Military Standard Data bus; the data format is defined by the NASA packet telemetry standard. A standard for commanding and telemetry is provided without restricting instrument design.

Similarly, the mechanical aspects of the instrument panels are defined for both dimensions and mounting points. Definitions of the actual positional placements or sizes of the instruments are not initially of major significance, with the exception of field-of-view limitation.

Mass and power within the shuttle bay are both defined within large margins above the requested instrument needs, allowing growth. Due to battery limitations, large power margins are not possible in the detached phase of the mission. Together, instrument placement, volume, power, and mass are considered without unduly restricting instrument design or development.

4.2.2.2 Verification of Subsatellite Data-Handling Interface.

At the PDR, as the instrument moves from design to development, a data interface simulator is provided. This simulator enables testing of electrical interfaces during instrument development, while modification is less costly than in later phases.

An instrument multi-point grounding philosophy is currently required. This reduces the possibility of unexpected instrument integration problems resulting from ground loops.

4.2.2.3 Verification of Subsatellite Mechanical Interface.

A flight-like panel is provided at the time of the Critical Design Review (CDR), as the instrument passes from preliminary development into flight fabrication. The instruments will be secured to the panel when fabrication is complete.

4.2.2.4 Environmental Qualification.

After fabrication, the instrument must pass general environmental qualifications, while mounted on the flight-like panel.

4.2.2.5 Pre-ship Review.

A pre-ship review is performed as the final phase is about to commence, before the actual integration of the instrument onto the subsatellite. During this final phase, a significant effort is made to detect, isolate, and correct last minute problems before the instrument is assigned, along with associated support equipment and personnel, to the integration facility.

4.2.2.6 Pre-Launch Baseline Testing.

Following integration, and prior to launch, a pre-flight series of baseline tests will be performed. These tests are defined in the Instruments Requirements Document (IRD).

4.2.3 Summary

The instrument integration strategy outlined throughout this subsection, provides early definition of the interfaces external to the various instruments, while allowing flexibility in instrument design.

Ideally, the major portion of instrument/subsatellite interface verification is conducted prior to system integration. This procedure allows adequate time to integrate the instruments onto the subsatellite.

4.3 DATA HANDLING SUBSYSTEM (DHS) - POTENTIAL UPGRADE

The Data Handling Subsystem (DHS) receives commands, and collects and formats telemetry data for transmission to Earth. Figure 4-14 presents a diagram showing how the DHS connects with other subsystems in the IMPS subsatellite. Commands from the Shuttle are received by the spacecraft directly or via transponder, and thence sent to the DHS. The DHS decodes and reformats these commands and executes or forwards them. Different subsystems generate telemetry data from internal engineering functions and/or sensors. The DHS collects the data streams from each instrument, integrates these streams together into one stream and transmits this stream (directly or by transponder) to the Shuttle, and ultimately, to the Earth.

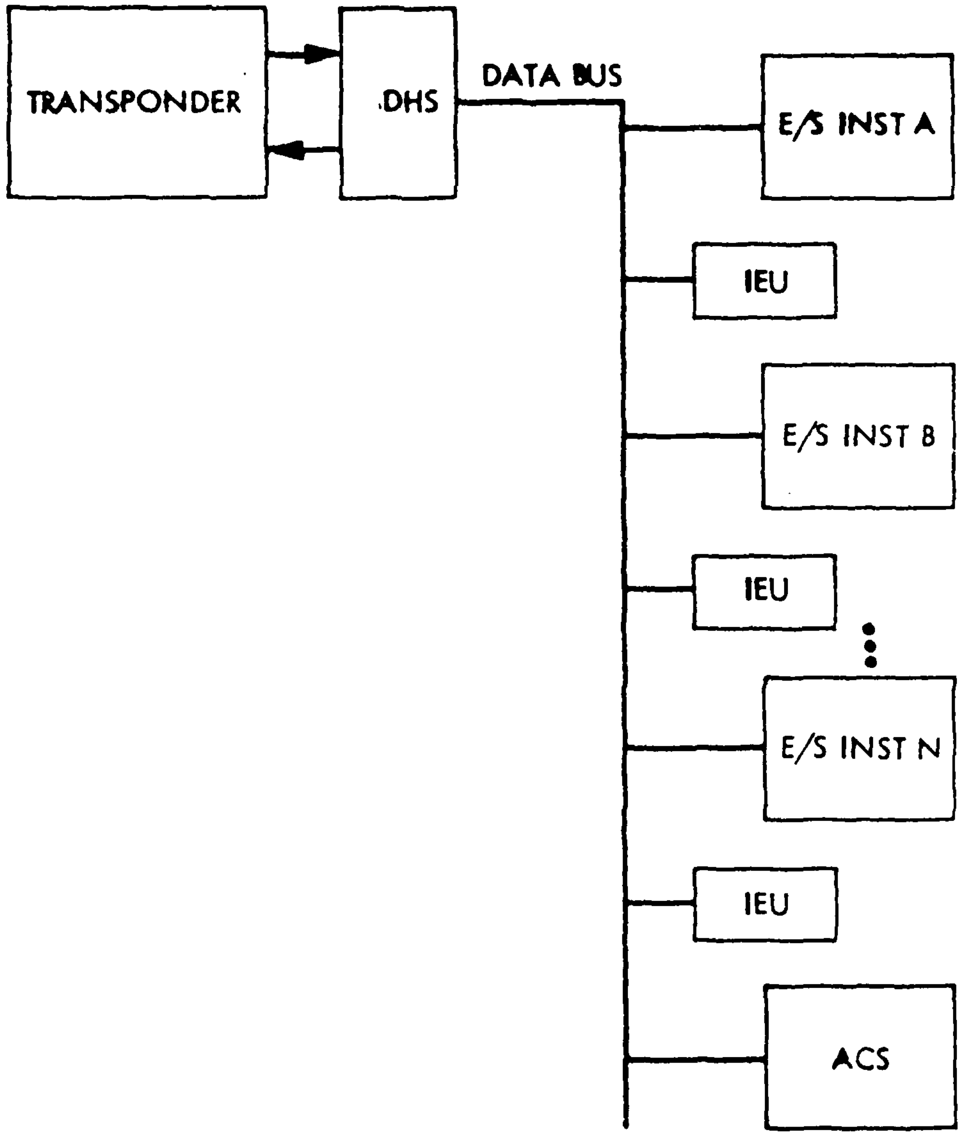


Figure 4-14. DHS Connections with IMPS Subsystems

4.3.1 DHS Requirements

The purpose of the IMPS flight is to provide for analysis of an integrated set of engineering/science data of the near-Earth polar orbit and auroral environments as well as the subsatellite interactions with large space systems. Part of the payload will be gathering data to support the measurements taken by the other instruments. Supplying a set of integrated measurements and correlatable data is an important objective of the IMPS missions. Because of projected reflights of the IMPS spacecraft, the DHS design will also facilitate the integration of instruments onto the spacecraft.

4.3.2 DHS Approach to the Requirements

The two IMPS design requirements identified in 4.3.1 have motivated the IMPS DHS design group toward using a serial data bus architecture. The data bus will return the data to the telemetry module, where the telemetry will be integrated into the final stream of source packets. Each of these packets will contain the spacecraft time at which the packet was generated, so instrument data can be cross-correlated after an IMPS flight.

Since the IMPS carrier will be flown several times, it is important that the interface between the E/S instruments and the DHS be standard within each mission and from mission to mission. The interface must be capable of allowing the DHS to complete its functions without reconfiguration, modification, or reverification of either hardware or software.

4.3.3 DHS Architecture

The DHS is designed as a partially redundant distributed data subsystem intended to maximize mission-to-mission inheritability and minimize mission-to-mission changes within the cost and schedule constraints of the IMPS project. The DHS will do this by having redundant command modules and communications buses, and a single telemetry module. The use of the instrument engineering unit (IEU) will help standardize that instrument's interface. The DHS architecture is depicted in Figure 4-15 by a block diagram.

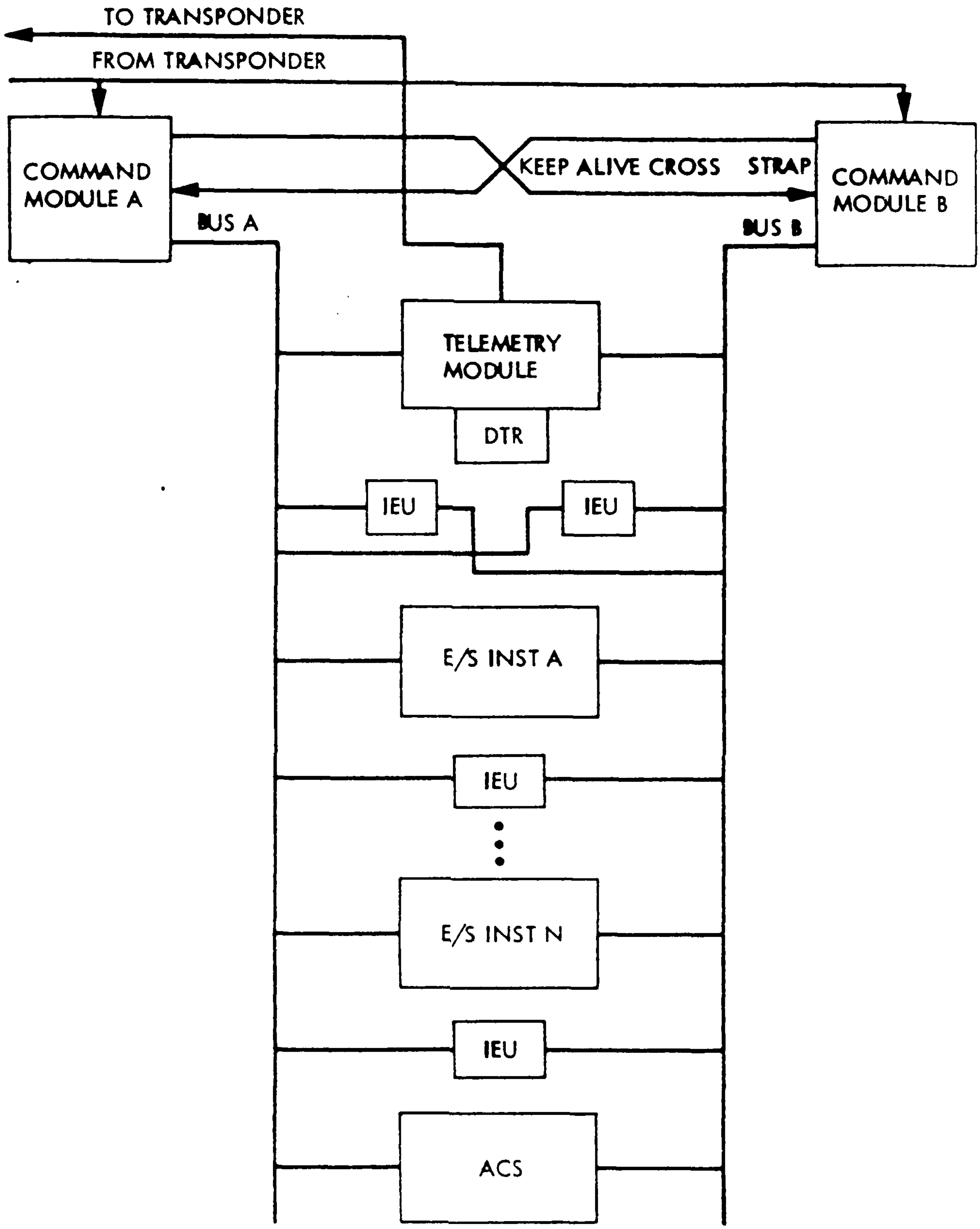


Figure 4-15. DHS block diagram

Commands:

Commands will be sent from the Shuttle Orbiter directly (attached mode) or by transponder radio link (free-flying mode). The commands pertaining to the commanding or communications functions will be executed by the Command Module. Other commands will be transmitted over the bus to the proper DHS module, IEU, or E/S (engineering/science) instrument.

Telemetry:

Telemetry (both engineering and E/S data) will be collected from the other DHS modules, IEUs and E/S instruments over the active bus and sent to the telemetry module, where this data will be properly formatted and sent to the Shuttle Orbiter directly (attached mode) or by transponder radio link (free-flyer mode).

Bus and Communications Architecture:

This subsystem is tied together by one of the two buses. Only one bus is operating at any one time, and it is under the control of the active command module. The bus will be used for virtually all communications between active modules within the DHS, and between the DHS and other spacecraft subsystems and engineering/science instruments. The major exception is the connections between the DHS and the transponder.

In order to decrease cost and increase spacecraft modularity, a standard interface to the bus shall be used. That means that specific hardware shall be used for each E/S instrument, and particular software shall be specified to reduce the amount of special fitting required.

Instrument Engineering Units:

The Instrument Engineering Units (IEU) are intended for the basic purpose of interfacing analog-to-digital (A/D) and power switching functions to the bus communications protocols. The need for these functions is on the

spacecraft. However, they are traditionally handled by centralized hardware modules with cabling running from the distributed need to the centralized providers of these services. The use of the IEU helps to greatly increase the modularity of the spacecraft design.

A secondary use of the IEU is to serve as a bus interface device for E/S instruments that do not contain a microprocessor. Since a microprocessor is needed to communicate over the DHS bus, some means must be provided to interface instruments without microprocessors to the bus. One method will be to use an IEU with expanded capability to do the interfacing. The IEU will maintain the standard interface to the DHS bus, while allowing special interfaces to be developed for certain instruments. This IEU to Instrument interface can be developed in parallel with the DHS to IEU interface. This type of parallel development will eliminate possible problems within the instrument or the DHS from affecting one another's schedules.

4.3.4 Intersubsystem Communications and Interface

The IMPS subsatellite will have two types of electrical interface between the subsystems and the E/S instruments: power and data communications. The power distribution will be a basic +28 volt power system. Data communications will be handled by a relatively complex message-based, bus-oriented, distributed-computer communications system.

Communications Protocol:

This subsection describes the protocol used by the different DHS modules and the different subsystems and E/S instruments enabling them to intercommunicate. The term "application" will be used to describe any software function in an DHS module, subsystem, or E/S instrument that has a need to communicate over the bus.

1) Interapplication Messages

The protocol used by the IMPS DHS for communications over the bus will be message-oriented. This means that the originating application will send a message to the receiving application. Many things will happen to the message before it is received by the receiving application; however, neither the transmitting nor receiving application will see any of these things taking place. The receiving application will receive the message reassembled to its original form.

2) Virtual Channels

The communications software sets up a "virtual" communications channel between the two communicating applications. This means that within the constraints placed by the lower functions of the protocol, the applications will virtually have a direct channel between them as shown in Figure 4-16.

Even though small transactions will actually be sent over the data bus, the applications will think that messages are being transmitted directly between them.

3) Protocol Layers

The protocol for the bus communications is made up of a number of layers. Each layer is designed to do a specific job. When a message is transmitted, each layer will receive input from the layer above it, and do its transformation on the message or transaction (depending upon the exact layer in question) and pass the results to the next lower layer. Likewise, when a message is received, a layer will get an input nearly identical to the output of the same layer in the transmitting module. Because of this feature, it will appear as though there are virtual channels set up between the same layer in the transmitting and receiving modules.

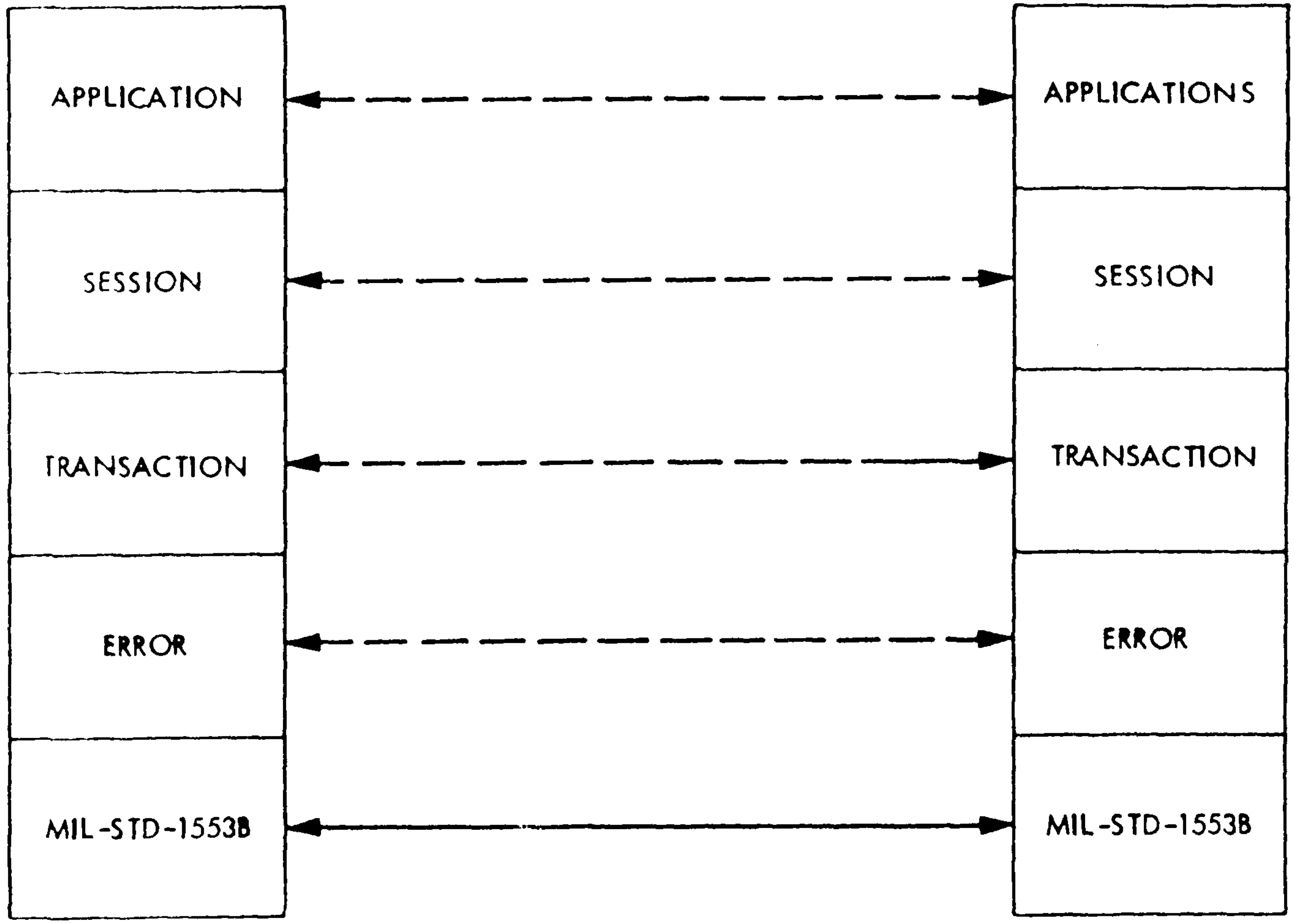


Figure 4-16. Virtual Communications Between Like Layers

The following paragraphs provide a brief description of the layers that make up the protocol. Figure 4-20 provides an illumination of the protocol layers.

APPLICATIONS LAYER. The term "applications layer" refers to the software in the DHS module, subsystem, or E/S instrument that needs communications services. The applications layer is the user software that performs the different processing functions of the module, subsystem, or instrument.

SESSION LAYER. The session layer sets up the communications session with the other session layer. The transmitting applications layer will give the message to its session layer. The session layer will then set up the path between itself and the session layer, just below the receiving applications layer. The actual path will occur through the layers below the session layer in both the transmitting and receiving modules.

TRANSACTION LAYER. In the transmitting module, the transaction layer will take the message generated in the applications layer, and break it into the proper size for the transactions used by the bus protocol. For the IMPS, the MIL-STD-1553B bus has a maximum transaction size of 32 data words (plus transaction headers). Therefore, in the IMPS spacecraft, the transaction layer will break the messages up into transactions containing 32 words or less.

Likewise, for the receiving module, the transaction layer will receive the transactions, re-order them into the proper sequence, and reconstruct the original message from these transactions. The transaction layer will then transfer the complete message to the session layer.

ERROR LAYER. The error layer ensures that the transaction layer receives errorless transactions. This layer is more of an error-recovery layer because most of the error detection takes

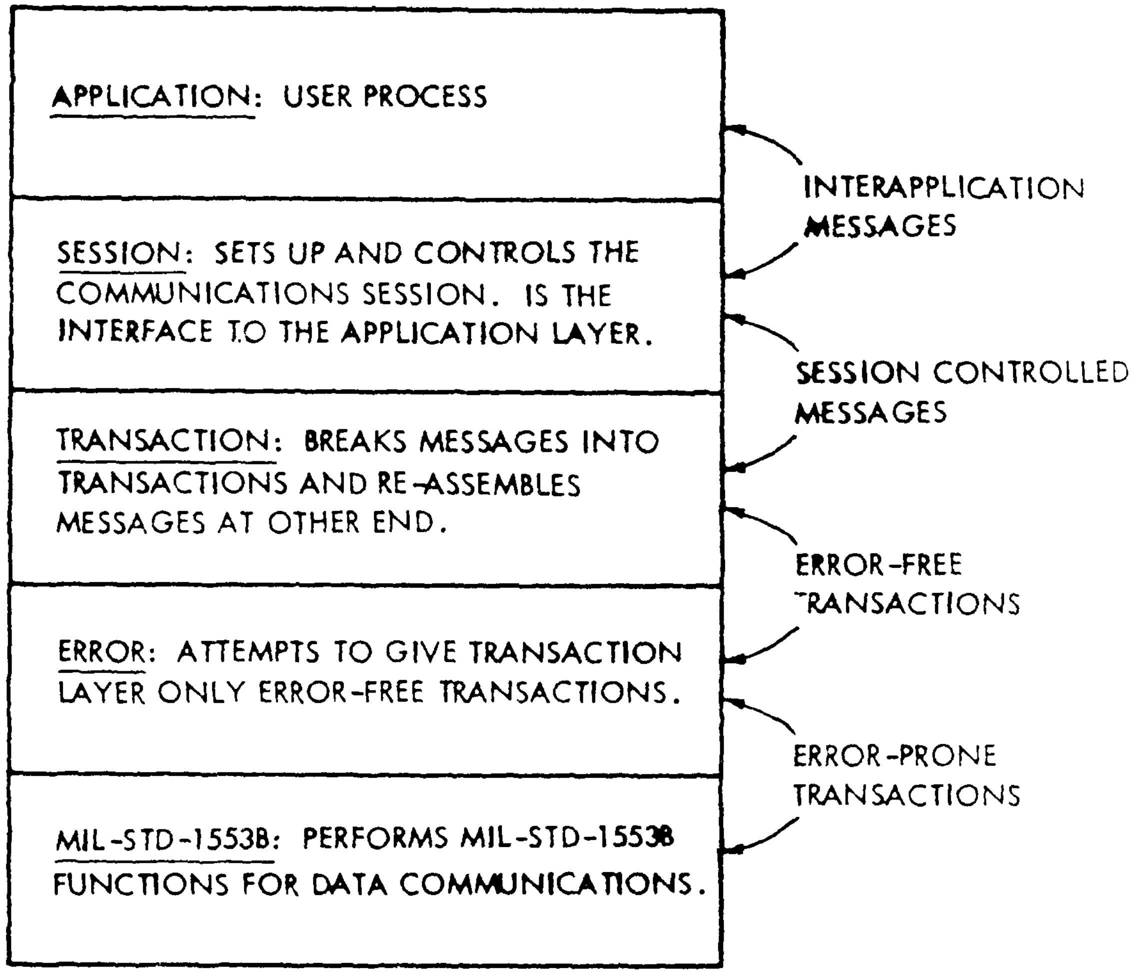


Figure 4-17. Protocol Layers and Interlayer Units Passage

place in the MIL-STD-1553B layer. One method of recovering from errors is by asking transmitting error layer to retransmit the transactions with errors.

MIL-STD-1553B LAYER. The rest of the functions needed for the transmission of data from one computer to another is taken up by the lowest layer in this protocol: the MIL-STD-1553B layer. Its multiple functions include: detecting errors and controlling the bus transactions, generating each word in the transaction, generating proper waveforms, transmitting, propagating, and receiving waveforms.

The Interface as Seen by an E/S Instrument:

The data communications interface is a simple interface for an E/S instrument. It only needs to decide to send a message, know what the message is, and who the message goes to. When the message is in the proper form, it is given to the session (or highest) layer of the protocol, and the message is transmitted error-free to the receiving application layer. The remaining functions required to transmit the message are handled by the protocol.

4.3.5 Command Function

Three subfunctions of the command functions are performed by the IMPS DHS: command decoding, commanding, and configuration control.

Command Decoding:

The uplink to the IMPS may require error detection and correction codes to guarantee sufficient quality (bit error rate) in the uplink. Specific algorithms for decoding and accepting or rejecting commands are well known and will be implemented, using hard-wired logic or ROM-based software. These techniques will enable commands to be decoded in almost any condition, including after temporary loss of power.

Commanding:

The DHS will issue commands to the spacecraft that have originated from the STS or from the ground facility via the STS. The IMPS is dependent therefore, upon the STS-to-IMPS link for the proper IMPS commanding capability.

Command Types

There are two types of commands that the DHS will be able to perform: real-time and store sequence commands.

REAL-TIME COMMANDS. Real-time commands are performed as they are received by the DHS command module.

STORED SEQUENCE COMMANDS. Stored sequence commands are sets of commands that are loaded into the DHS memories before the launch or during the mission (via the uplink). The commands that make up the sequence are intended to be performed in the same sequence as they are listed. Each of these commands, however, is also associated with a time word. As the command function goes down the list of commands, it waits to execute each command at the time indicated by the command's associated time word.

Command Execution

Commands will be decoded in the command module where they will be forwarded to the software that does the actual commanding. Some commands will be executed immediately, while others will be executed later as part of a sequence. When commands are executed, they are separated into commands for the command and communications functions (located in the command module), and commands for any other functions, subsystems or instrument. Command module commands are directly executed in the command module, while all other commands are forwarded to their proper destination by means of a message over the DHS bus. When a command message is sent to another subsystem or instrument, the command becomes a forwarded

command. The result of forwarded commands shall not depend upon the other commands (sequencing or real-time) performed by the DHS. Any command whether intended for the command module or as a forwarded command, may cause a number of actions to occur. These are macro commands and they are used to reduce the number of actual commands stored for cases of repetitive or common command sequences.

Spacecraft Configuration Control:

The DHS will control the selection of any primary or backup modules that may make up the subsystems on board the IMPS spacecraft.

4.3.6 Telemetry Function

The telemetry function of the DHS will collect telemetry from various sources in the form of packets, integrate these packets into a packet stream, and add sufficient sync data to allow the ground system to recover the original packets of telemetry data. The packet type of telemetry is necessary because of the requirement that the IMPS spacecraft be reflown with completely different payload complements. By comparison, a Time Division Multiplexed (TDM) type of telemetry system would greatly increase the amount of work required to ready the IMPS spacecraft for reflights, and would impose more restrictions on the designs of the E/S instrument.

CCSDS Packet Telemetry Standards:

The following discussion of the Consultative Committee for Space Data Systems (CCSDS) packet telemetry standards is brief and incomplete. Detailed information can be found in the CCSDS Recommendations for Space Data System Standards: Packet Telemetry, "Blue Book".

There are two parts to the packet telemetry standards: the packets of data, and the framing information that allows the ground system to find the packets. The CCSDS standard uses a technique called transfer frames for accomplishing the latter parts of framing information.

1) Packets

Figure 4-18 shows the format of the telemetry packets that will be used by IMPS. The packet is made up of two parts: the header (primary and secondary), and the data (with optional error control field). The total packet length can be of different sizes between 1024 and 8192 bits. Longer packets will be handled by segmentation procedures.

PRIMARY HEADER. The primary header contains all of the information necessary for the spacecraft and the ground to deliver the packet to the instrument-unique ground processing equipment. Some of the fields in the primary header are also of interest.

An application process ID will identify which spacecraft process has generated the packet. There may be more than one process occurring in a particular piece of hardware. The eleven bits of this ID field should be sufficient for IMPS, since the MIL-STD-1553B data bus will have five bits of address and four bits of subaddress, for a total of nine bits of process ID.

The Source Sequence Count is a simple serial count of the packets that are generated by an application process. This count will allow the ground to detect missing packets, and reorder packets that have somehow gotten out of sequence. If one instrument were to have more than one application process, then each of the applications would calculate an independent Source Sequence Count.

The packet length is the total number of 16-bit words that make up the packet. 16-bit words are used throughout the standard, which is why they are counted in the packet length field (see Figure 4-18),

SECONDARY HEADER. The secondary header contains data necessary for preliminary instrument-unique ground process such as: spacecraft time at packet generation, packet format data, and other ancillary

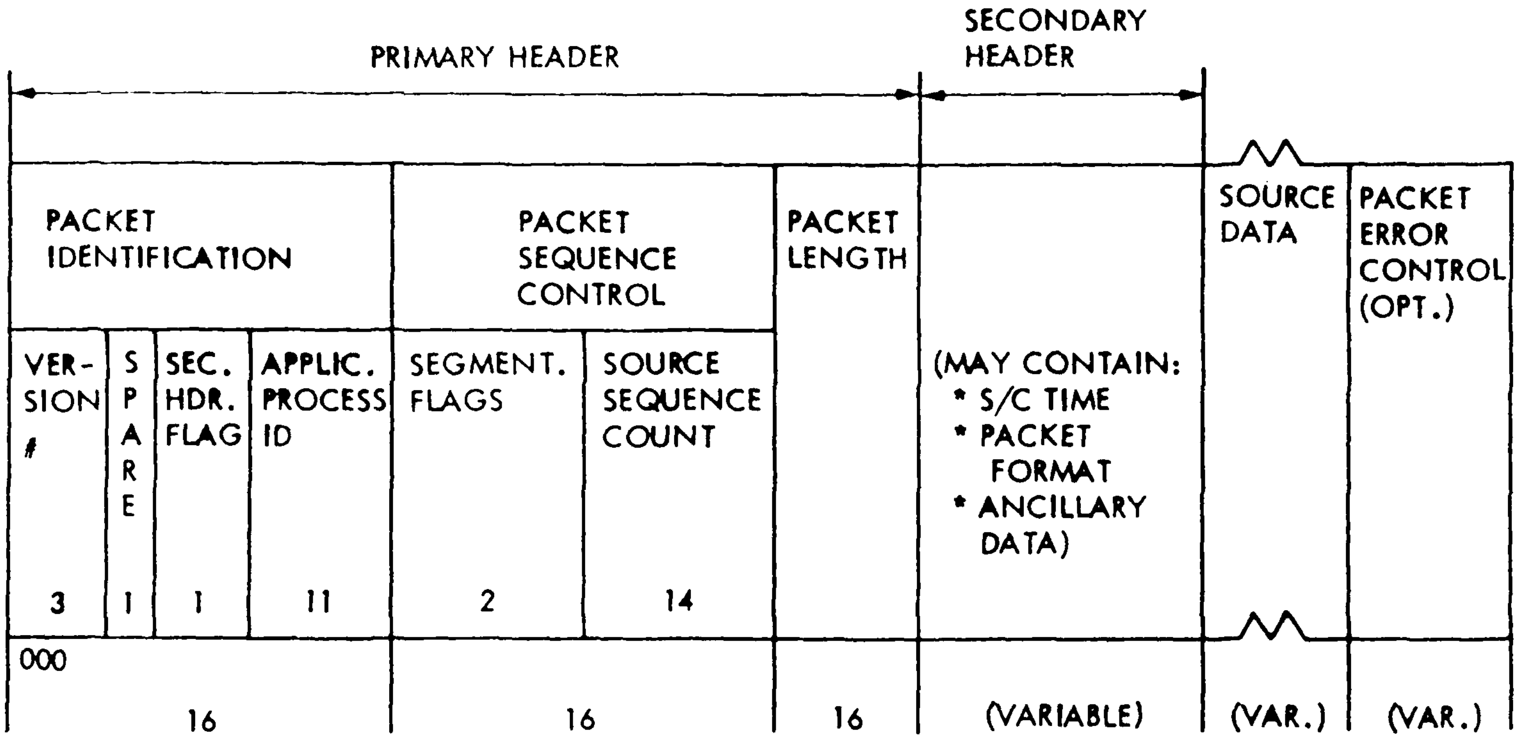


Figure 4-18. Telemetry "Source Packet" Format

data. Since this header contains no information of interest to the non-instrument-unique spacecraft ground systems, this header is of no further interest to this report.

SOURCE DATA. The source data is the IMPS engineering/science data to be downlinked by the packet.

PACKET ERROR CONTROL. This is an optional field in the packet that will allow the process to decrease the bit error rate of the downlink, if necessary. This field does not affect the spacecraft and ground systems.

2) Transfer Frames

The process of generating and collecting source packets can be independent and asynchronous to the transfer framing process. Figure 4-19 shows how several packets from several packet sources can be integrated into a packet stream. The next step is to generate the transfer frames. Transfer frames of equal length are generated, and transfer frame headers are then generated and placed into the packet stream. The packets can be asynchronous to the transfer frames by having a field in the header that points to the beginning of the first packet header in that frame. This field is shown at the end of the primary transfer frame header in Figure 4-20.

The sync mark allows the ground to sync onto the transfer frame. This sync pattern is unchanging and always devotes the same number of bits apart. Therefore, the transfer frame performs many of the same functions as the minor frame in the traditional TDM type of telemetry system, but with far greater flexibility.

The IMPS telemetry transmitted to the STS orbiter will include certain data that STS must be able to monitor. The STS has been designed long before the packet telemetry standards were

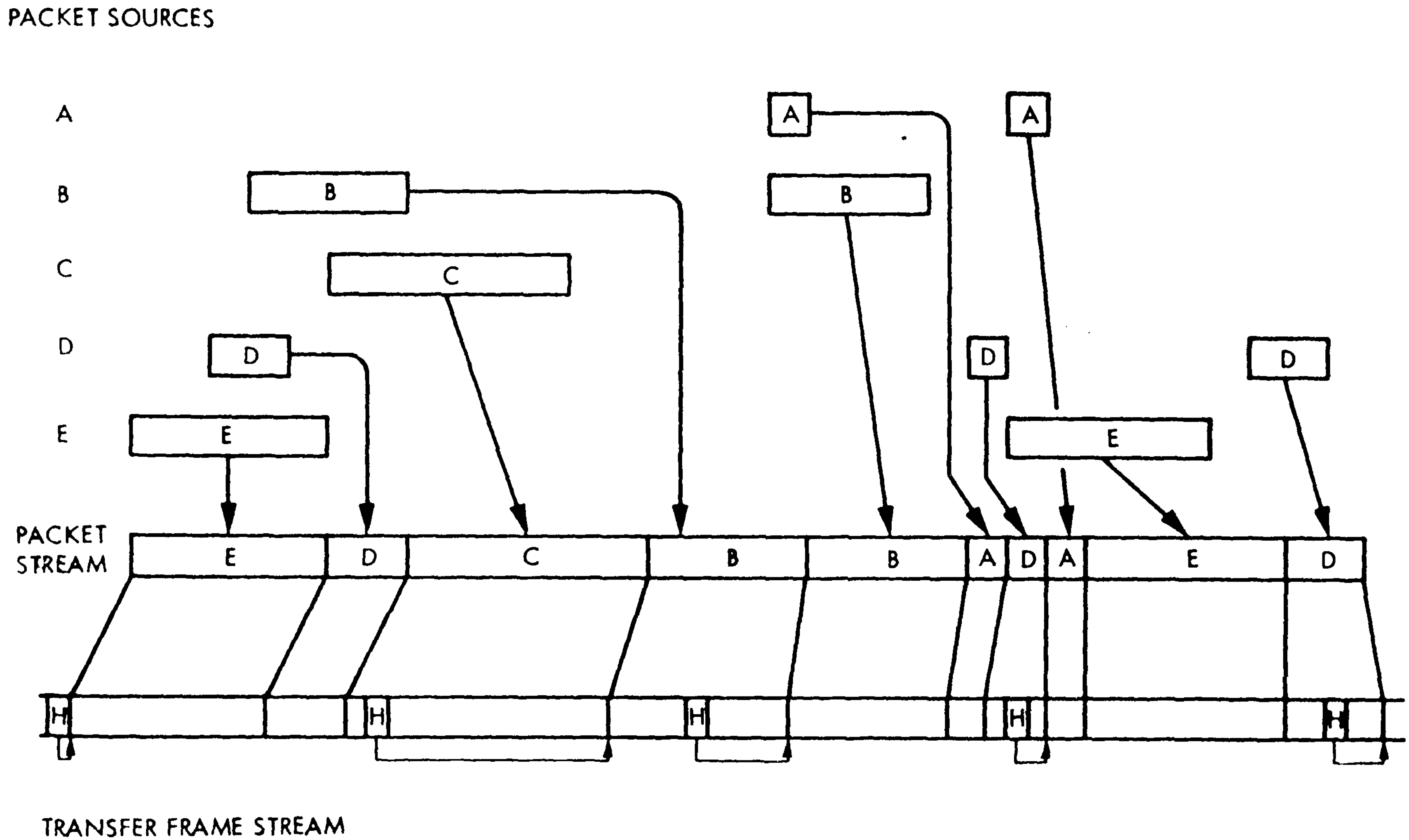


Figure 4-19. Packets Integrating into Packet Stream

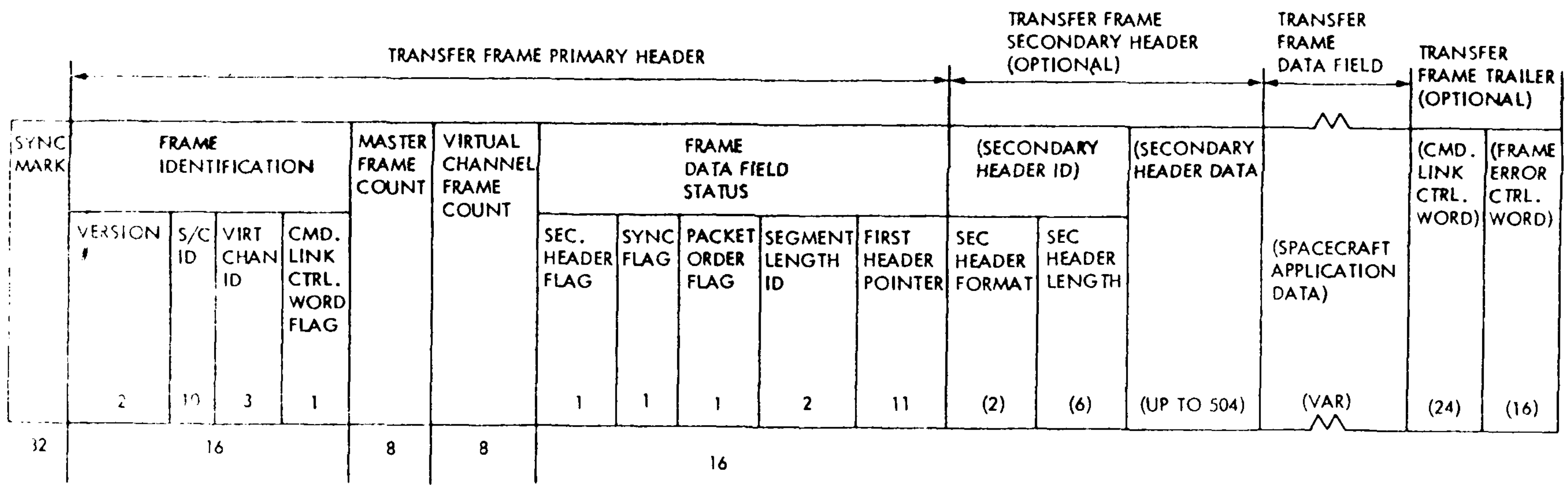


Figure 4-20. Version I Transfer Frame Header Format

accepted, so it would not be able to pick packets out of this telemetry stream. However, this type of data can be placed into the secondary header of every transfer frame. This allows the STS to pick out the proper IMPS data from a system that looks like a TDM system, while enabling the IMPS to use a packet telemetry system.

Engineering Telemetry:

The classic type of engineering telemetry consists of measurements, such as voltages, temperatures, currents, etc. These analog measurements are all taken by IEUs that are situated around the spacecraft. There will be one IEU taking measurements for each E/S instrument, along with two to four IEUs with augmented analog inputs spread around the spacecraft to collect spacecraft generic and subsystem analog engineering data.

Other engineering data consists of the data generated in a digital format, and associated with digitally controlled processes. This includes flags, counters, and status registers which indicate the status and health of the hardware and software that make up the DHS. Other spacecraft subsystems may also generate this type of engineering data, however, any digital (or analog) engineering data generated by the E/S instruments will be included in that instrument's packet.

The engineering data discussed above will be collected by the telemetry module where the data will be formed into packets. These will be the engineering telemetry packets, and they will be given an appropriate packet ID. The engineering data that will be needed for status indication by the STS will be placed into the transport frame secondary header, as discussed under the title, Transfer Frames.

Engineering/Science (E/S) Telemetry:

The E/S instrument data will be made up of source packets. Each packet will be built by the instrument that has generated the data it

contains. Once the packet is removed from the instrument, packet will not be changed until it is dismantled by the instrument-unique ground system.

1) Packet Collection

The E/S instruments will be polled by the telemetry module, asking if they have a packet, and how large it is. The instruments with packets will reply, and the telemetry module will be responsible for integrating the packets into a packet stream.

Downlink bandwidth is considered a very limited resource, and it must be controlled by the telemetry module. It can only be changed by ground command. The instruments will also be controlled in bandwidths, so that the instrument and engineering total will add up to less than or equal to the available amount. Insufficient amounts of packet bandwidth are easily remedied by the spacecraft's ability to generate dummy packets. Those packets are discarded on the ground.

If the downlink bandwidth is too small, the telemetry module will assume that the problem is a short burst of data. This problem is best solved by buffering packets in the E/S instruments. However, the DHS will attempt to do temporary buffering until the spike in the particular instrument bandwidth has passed. If the spike is too long, or if it is permanent, the DHS will have no recourse except to start discarding excessive packets.

Telemetry Outputs

The telemetry module will take all packets that wish to be in the downlink and arrange them into a final packet stream, where the transfer frame headers are added, and the telemetry bit stream is created. Data needed by the STS Orbiter will be placed into transfer frame secondary headers.

3) Digital Tape Recorders

When data cannot be downlinked in real-time, they will be stored on a digital tape recorder on board the IMPS spacecraft.

4.3.7 Fault Protection Function

Command Module Switching:

During normal operations, only one command module and bus are powered and in operation. However, the power-down command module will have a hardware watch-dog timer that will be cross-strapped to the other command module. The active command module will be required to write to the other watch-dog timer. If that does not happen, the watch-dog timer will assume that the active command module has failed, and switch to the other command module.

Other fault protection functions are carrier loss and power undervoltage.

4.4 GROUND DATA SYSTEM - POTENTIAL UPGRADE

The IMPS ground system will be a set of hardware and software specifically configured to interpret telemetry from, and issue commands to, the IMPS subsatellite. It will serve the IMPS flight control personnel and the IMPS experimenters. The ground system will communicate with the subsatellite through the NASA and/or AF communication system. Implementing this ground system will be phased over the life of the IMPS program; only a partial implementation will be in place for IMPS-1 deployment.

4.4.1 Design Considerations

There are three important considerations in the design of the IMPS ground system:

1) IMPS will be a set of similar, but different missions. Each mission will utilize different mission parameters. The ground system must be adaptable to these varying mission parameters.

2) The IMPS flight plan remain changeable during flight. Unforeseen events may alter the flight plan, i.e., the shuttle launch may be delayed; or there may be a failure on the subsatellite, or there may occur an unusual phenomenon worthy of closer observation. The IMPS flight plan must be able to accommodate these events,as well as short notice modifications in the mission sequence.

3) IMPS must be able to easily accommodate new instruments. Typically, there will be little time to integrate science instruments into the payload. The ground system should provide standardized command and telemetry protocol to the new instruments or investigations so as to simplify and facilitate integration.

4.4.2 Hardware

Local Area Network:

The backbone of the IMPS ground system will be a local area network (LAN) like Ethernet. It will link together the minicomputers, microcomputers, printers, and other equipment, and will enable them to exchange information at high speeds. Figure 4-21 is a block diagram of the ground system hardware.

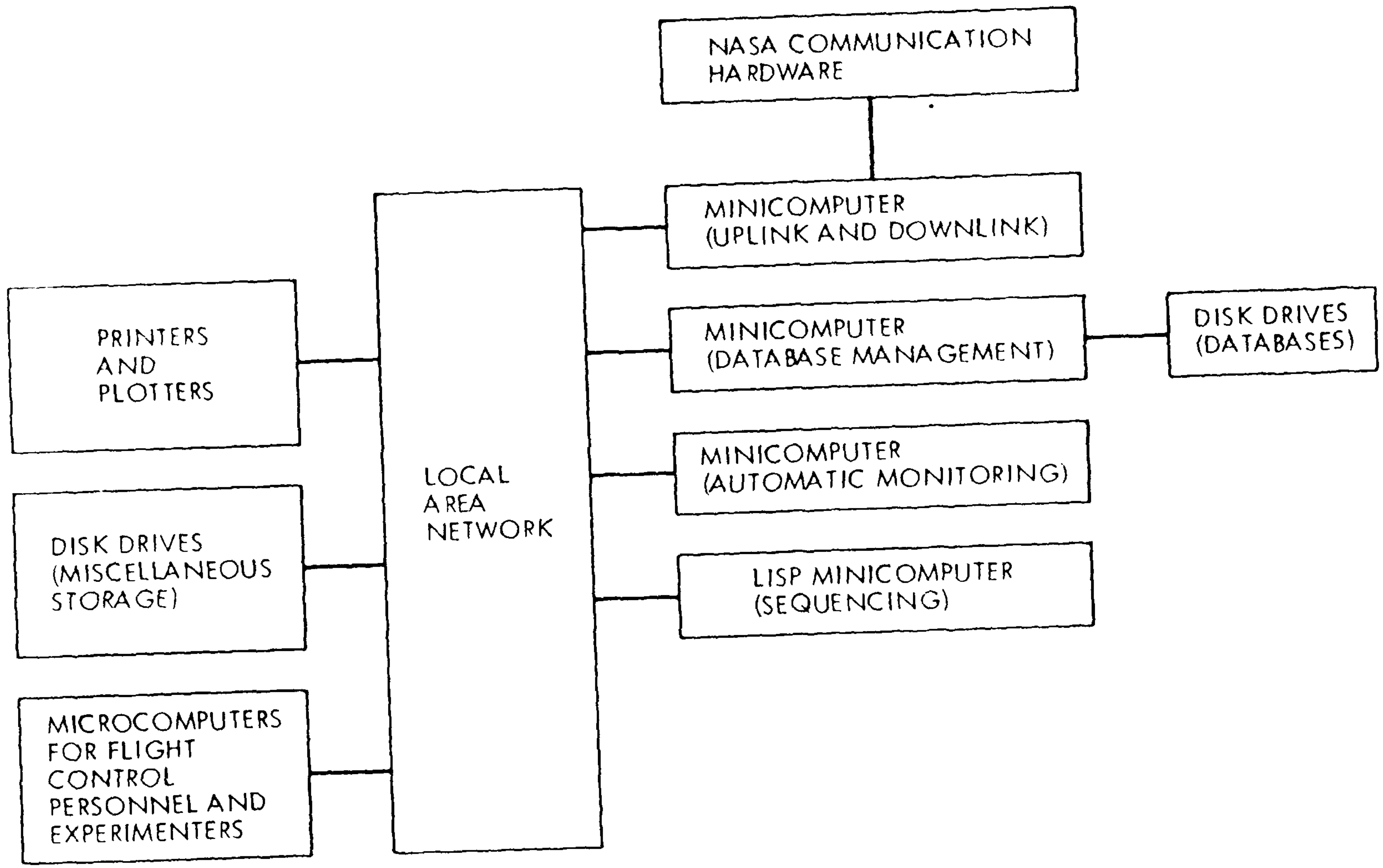


Figure 4-21. Block Diagram of Ground System Hardware

Minicomputers:

Minicomputers such as the VAX and the Symbolics computers will perform several functions. The VAX class minicomputers will maintain the large databases required by the ground system software, interface with NASA communication network, and automatically monitor certain critical measurements and indicate any problems. The Symbolic micro computer will run the expert planning software that will develop the flights' sequence of events.

There will be several minicomputers in the ground system. They will distribute the processing load efficiently and supply redundancy in the case of failure by one of other processors.

Microcomputers:

Microcomputers like the IBM PC will serve as the consoles from which the flight control personnel and the experimenters will monitor telemetry data and issue commands. The micro computers will be the links between ground support personnel and the ground system service. Prior to flight, these microcomputers will serve another important task for the experimenters. By connecting the microcomputers to the instruments through proper hardware interface and using software to simulate the ground system software, the microcomputers will represent a stand-alone verification of the tested instrument's compatibility with the ground system's command and telemetry protocols. The experimenters in the laboratory will be able to issue commands and receive data from the instrument under test, exactly as will be done when the microcomputer is connected with the actual ground system during flight.

4.4.3 Telemetry

The telemetry system will receive data from the subsatellite through the NASA and AF communication networks. It will accept the information in the standard NASA packet format, and will disseminate the data to the experimenters, the flight control personnel, and all other sequences of the ground system. A block diagram of the telemetry flow is provided in Figure 4-22.

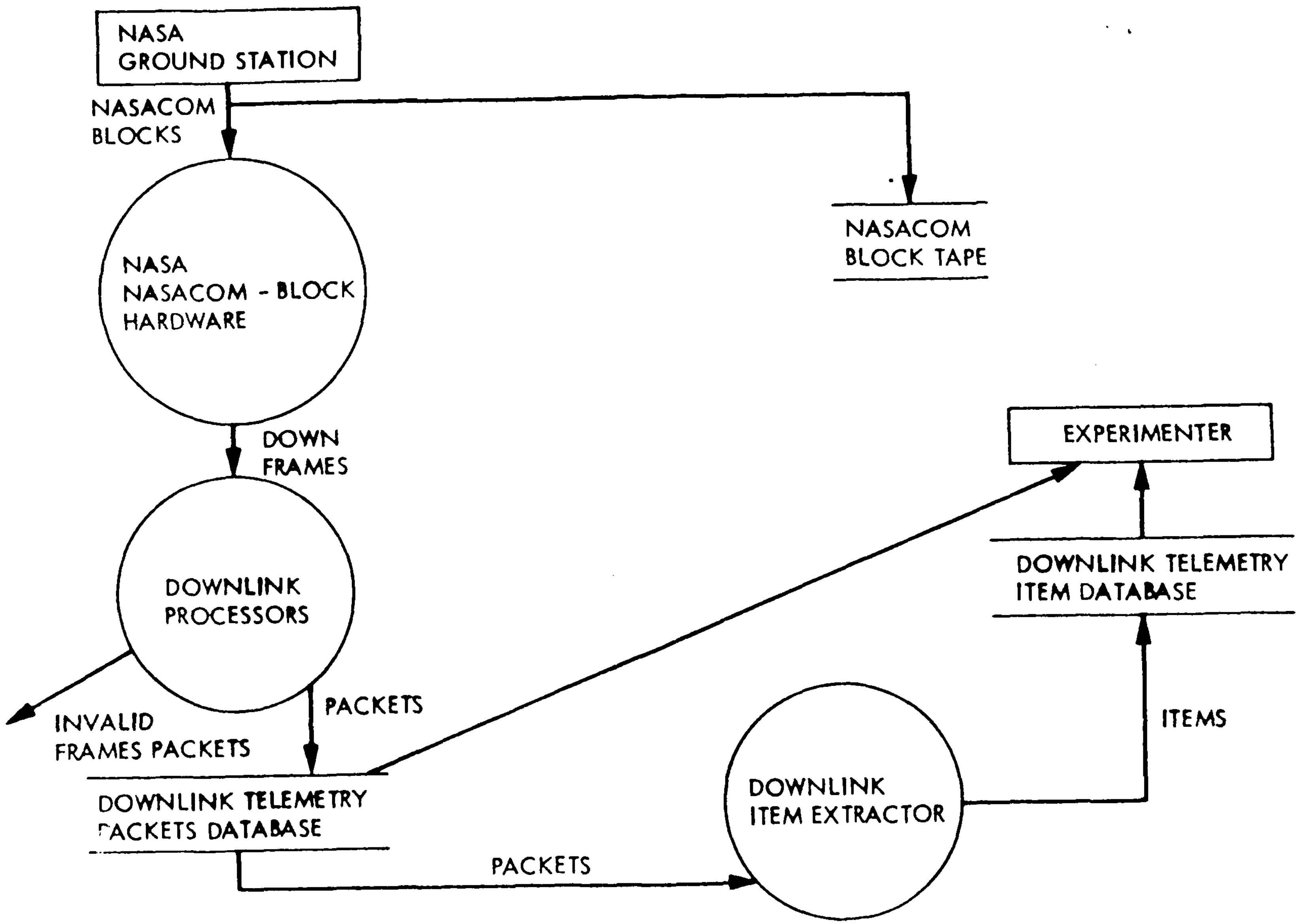


Figure 4-22. Telemetry Flow Block Diagram

Objectives:

Two objectives have governed the design of the telemetry system:

1)Provide data to the experimenter in a format less complicated than the packetized communication by which it has been received.

2)Make the data readily available to the various individuals and monitoring processes at the ground system.

Downlink Telemetry Database:

All telemetry data received during the mission will be stored in a downlink telemetry database. This data base will serve as the one source of telemetry data for the entire ground system. The experimenters, flight control personnel, and automated processes will be able to request and obtain any sequent of data. In this manner, data can be delivered without the user knowing how the data has been downlinked. By requesting the next value of a particular data item, the user will be able to monitor the data in real-time. By requesting the values of data items over a particular time frame, the user will be able to review any sequence of data received in the course of the mission.

Displays:

The ground system software will provide many different formats to display the telemetry data on the screen of the user's microcomputer: rows of numbers, bar charts, plots over time, etc. It will also provide the ability to display several different data formats on one screen simultaneously.

4.4.4 Command

The command system will accept command requests from the users and will sequence them into the payload timeline automatically. A block diagram of the command system is presented in Figure 4-23. The ground system will issue commands to the IMPS through the NASA and AF communcation networks using a standard command packet format.

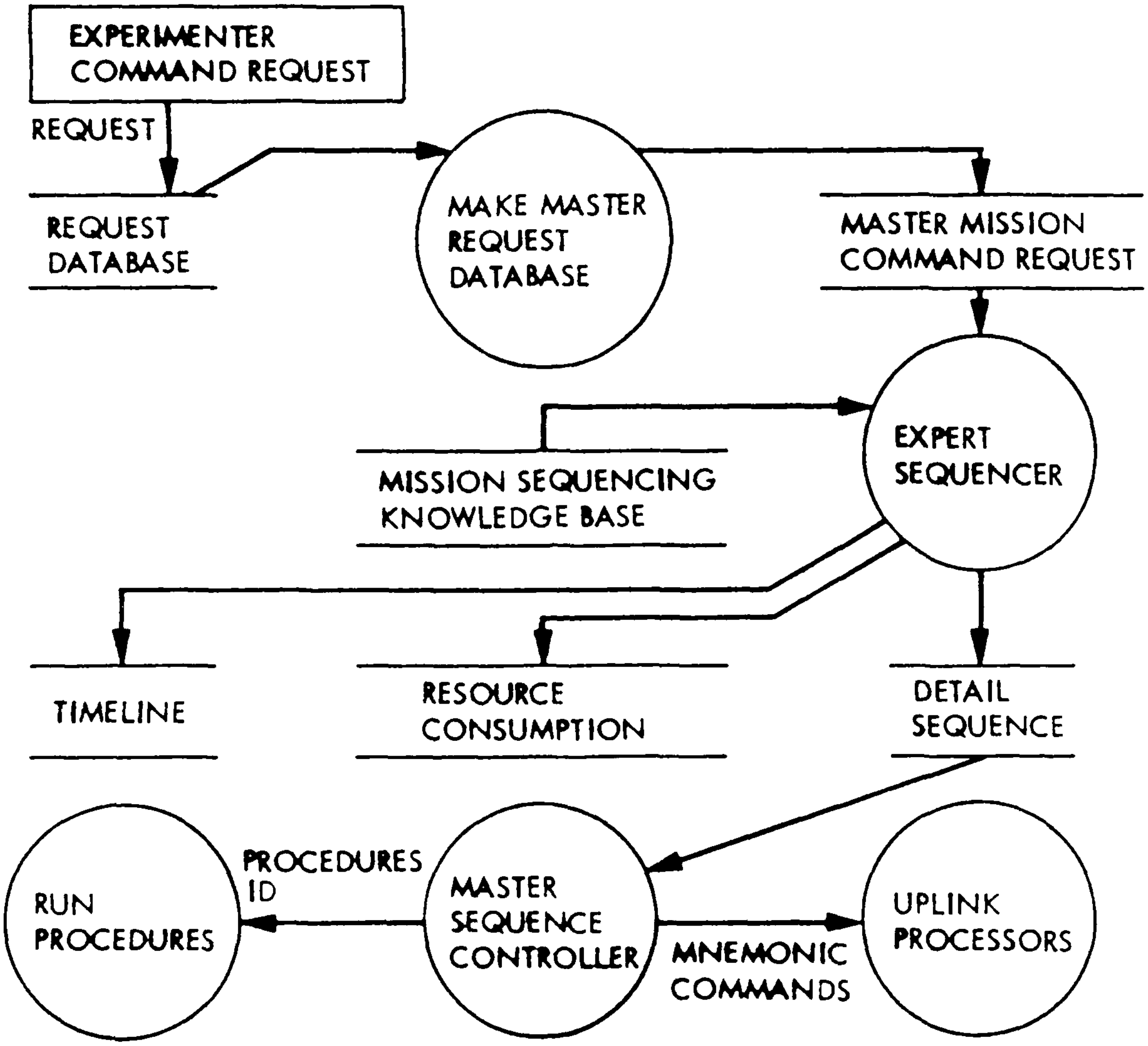


Figure 4-23. Command System Block Diagram

Command Request Database:

All command requests from experimenters and flight control personnel will be entered into a database called the command request database. The requests may specify statements like the specific instrument pointing angle or the particular operating period. The database will be copied, at specified intervals, into the master mission command request database.

Expert Planning Software:

The expert planning software will read all of the command requests from the master mission command request database and automatically generate the sequence of events and the corresponding timeline for the mission. It works with a knowledge base concerning the subsatellite resources, (mass, power, etc.), as well as with a set of rules on how to construct a sequence. The expert planning software will consider many different flight sequences and ultimately deciding on the one that most effectively accommodates as many of the command requests as possible. Expert planning software can do this scheduling in a matter of hours; by hand with calculator, flight sequencing may require weeks or months.

An expert planning software package currently under development at JPL is titled the Deviser. It is written in LISP and runs on a Symbolics minicomputer. The Deviser will be used to construct the flight sequences for the Voyager Uranus encounter in 1986 (Technology Demonstration), and is planned for use on the Spacelab and the Galileo spacecraft.

Master Sequence Controller:

The detailed listing of the mission timeline will be interpreted by another software package, the master sequence controller, which initiates the appropriate commands to the subsatellite at the appropriate times. The flight control personnel will be able to overide or terminate the master sequence controller and manually issue commands to the subsatellite.

Real-Time Command:

The ground system may supply the capability for experimenters to interactively control an experiment on board IMPS for short periods of time.

Replanning:

One of the IMPS mission objectives is to design for the ability to adapt to changes during flight. The flexible design of the ground system, with its command request databases and automatic sequencing software, makes this adaptive posture possible. In light of an auroral occurrence or some unforeseen event, such as a change in the Shuttle mission plan or the failure of a component on the payload, the mission time table can be resequenced in hours.

SECTION 5

ENGINEERING/SCIENCE

5.1 IMPS ADVANCED CONCEPTS PLAN

5.1.1 Introduction

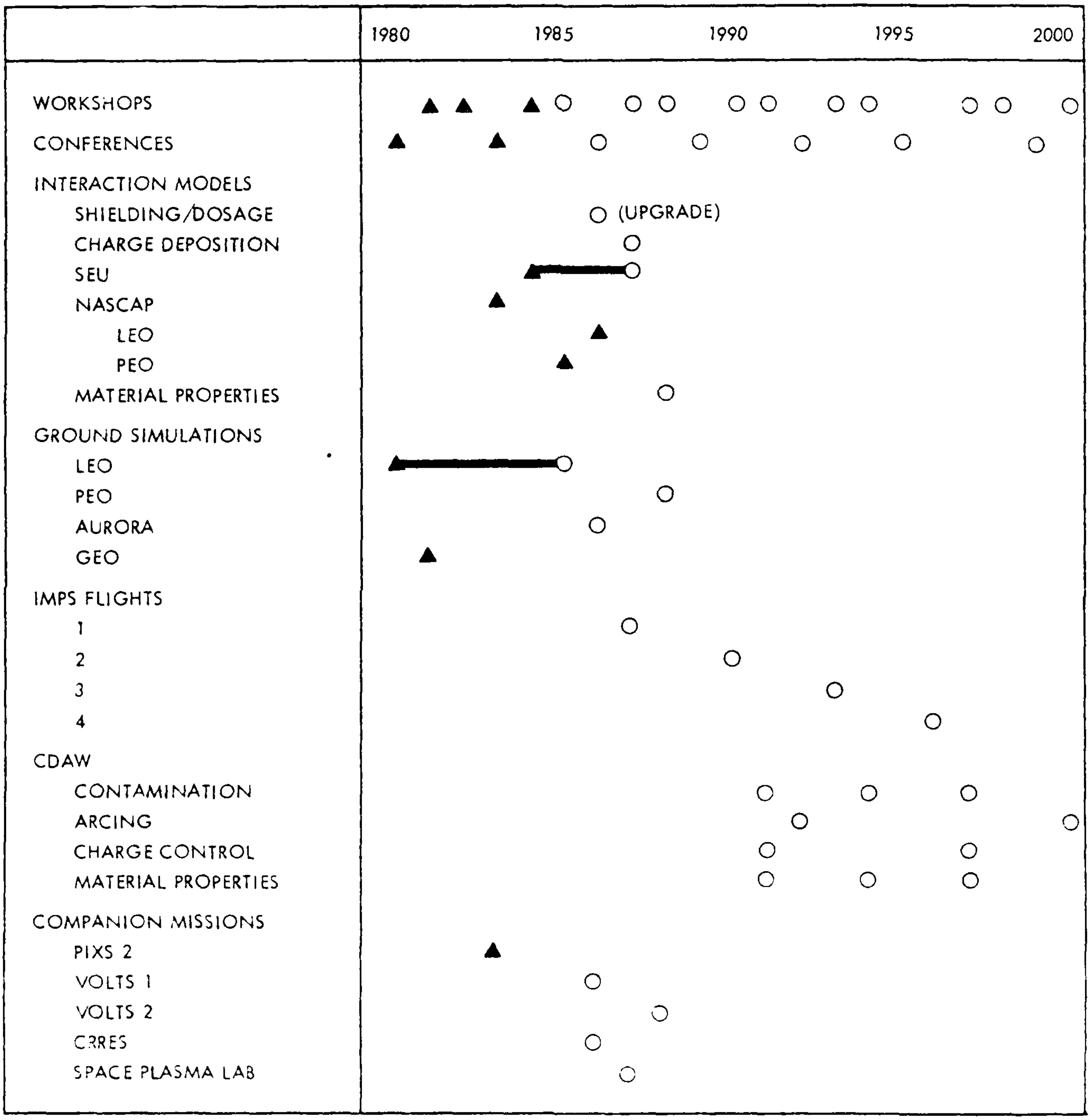
Several other missions, directly related to the IMPS program goals are currently planned for the same time frame. In order to obtain the maximum value from IMPS, it is necessary that IMPS be integrated into other planned efforts and that the IMPS extended program incorporate the results of these missions into its long range plan. In this section, such a long range plan will be developed with emphasis on future IMPS payloads and missions into different space environments. Although not intended as a detailed plan, the phased approach presented in this subsection provides the skeleton for such a program. Refer to Table 5-1 for the master time line for IMPS, 1980-2000.

In planning a long range space program with the scope of IMPS and its companion flights, a phased approach is a necessity. Here the advanced concepts plan is divided into four phases:

1) Information gathering phase
2) Simulation phase
3) Flight phase
4) Analysis phase

Each phase can co-extend with other phases, although certain phases will have been initiated earlier than others. Information relevant to each phase will be gathered during the course of the entire program and the process of reanalysis and evaluation will be repeated for each flight.

TABLE 5-1. Master Time Line for IMPS, 1980 - 2000



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5.1.2 Information Collection and Planning

The purpose of the first phase in the long range plan is data gathering. There are various methods of accomplishing this undertaking and, indeed, the ESWG has identification information collection as its primary objective. The four principal means that have been employed for data gathering are the following:

1) Collect documentation
2) Conduct workshops/conferences
3) Visit key facilities
4) Utilize a panel of experts (i.e., the ESWG)

As an illustration of the first method, numerous searches through scientific literature were carried out for AFGL on specific IMPS concerns by the ESWG and JPL. An extensive bibliography of papers on IMPS-related material were prepared for AFGL under this effort. Several reviews of spacecraft and plasma interactions were compiled. In reference to method two, a workshop was held in December 1981 and a joint AF/NASA conference in October of 1983. Several facilities such as NASA headquarters and AFWL were visited and data on IMPS collected with the assistance of the ESWG members, AFGL, and JPL.

Building on the IMPS database, future flights should concentrate on specific interaction concerns. If funding permits, workshops on specific interactions should become a continuing part of the IMPS long term program. In concert with these topical meetings, every two years a general conference should be held (Such a conference was last held in October 1983). Based on information from the workshops and the conferences, the data base of references on spacecraft interactions developed by the ESWG can be expanded and made permanent. The material in this database has been divided by interaction effects and is being cross-referenced to the specific systems affected.

Blue ribbon panels, like those represented by the ESWG, should be organized on a permanent basis to advise AFGL as to progress in mitigating the individual problems, as well as to future research. A master technology road map in the area of spacecraft interactions should be developed (the rudiments of such a plan actually exist within the joint AF/NASA technology program) based on the findings of these panels.

5.1.3 Simulation of Environmental Interactions

For the second phase, the main thrust will be to improve the capability to simulate interactions. Given the existence of the data base on spacecraft interactions developed in phase 1, the adequacy of the existing models and experimental data associated with the different interactions can be evaluated. This information can be used to determine where simulation capabilities need to be improved and where more data are required. Again, several approaches are necessary; and this too is a continuing process. Two approaches are considered here:

1) Theoretical modeling
2) Ground simulation

As in any scientific activity, the ability to control a given phenomenon is dependent on the adequacy of the theoretical constructs used to define it. In studies of spacecraft interactions, an adequate understanding of a phenomenon includes an understanding of the source (the environment), of the victim (the space system), and of the interaction (spacecraft charging, radiation damage, etc.). The model attempts to simulate the effects of the source on the system. Currently, although fairly adequate models of the space environment exist and systems can be modeled to some degree, interaction models are in general at a very rudimentary level (dosage and shielding calculations are an exception). Thus the development of adequate models is a primary concern.

Ground testing remains in most cases the cheapest and easiest way to study many phenomena associated with spacecraft interactions. Such ground simulation should be given as high a priority as the modeling efforts. The primary difficulty to date with ground testing has been problems with scaling of plasma phenomena and with simulation of the space plasma characteristics. In a departure from previous studies, it is recommended here that specific facilities be developed and dedicated to simulating each of the principal space plasma environments. Likewise, adequate simulations of particular phenomena are also necessary (launch conditions, rocket plume effects, arcing, high voltage surfaces, etc.).

5.1.4 Follow-on Missions

Several follow-on flights for IMPS are possible. The intent is to modify the IMPS payload so that the interactions typical of each key space regime (ionosphere, auroral zone, and polar region) discussed in this report are emphasized. Those missions, in chronological order, are:

1) IMPS-1--Polar earth orbit/auroral zone. This is the principal IMPS mission now envisioned and outlined in this report.

2) IMPS/VOLTS (IMPS-2)--Polar earth orbit/auroral zone. A joint mission with the NASA VOLTS array will be of mutual benefit to both programs. It will afford IMPS the possibility of flying with a large, high voltage structure. For VOLTS, the IMPS diagnostic capabilities will be of great value in studying interactions with the auroral and polar regions. As IMPS has been designed with such a misson in mind, no modification to the basic IMPS-1 package should be necessary.

3) IMPS-3--Low latitude plasmasphere/ionosphere-large structure. Although the primary IMPS mission will pass

through this regime, the mission is not optimized for this region, nor will it necessarily fly with a large structure (1 km or larger). An actual large structure (as opposed to the samples on IMPS-1) such as the prototype of the space based radar or an AF/NASA space station should be available by the time of this launch. Depending on the size and complexity of the structure, multiple environmental sensor packages can be deployed to simultaneously monitor the environment around the structure.

5.1.5 Analysis/Data Workshops

The most critical effort for IMPS will be the actual analysis of the data. Although as already indicated, invaluable data can be gained from ground testing. Analysis of actual flight data is the ultimate step in gaining a real understanding of interactions. Furthermore, for the IMPS program to be of any lasting value, that understanding must be documented. As turn-around is a crucial issue in adequately disseminating the IMPS data, a carefully conceived data analysis plan, incorporating real-time analysis, data workshops, and quantifiable outputs such as MIL-STDS is a necessity. Each of these subjects will be addressed for the IMPS and its companion missions in this section.

Real-time analysis of the IMPS data will be a requirement for some of the instruments. Although primarily automatic, IMPS instrumentation will require careful monitoring when particle sources (thrusters, etc.) are turned on or the subsatellite is moved to another position. Moreover, the status of the aurorae will require monitoring in real-time in order to predict the encounter of IMPS with an auroral arc. It is hoped, in fact, to have specific modes that the IMPS package can be configured in, so as to optimize data collection when passing through auroral features. With sufficient forethought, the data from such runs would be available for real-time analysis. It is recommended that at least one such optimized real-time run take place each day. Several candidates for such runs would be:

1) Auroral arc encounter: all instruments capable of recording rapid variations should be in their highest time resolution modes and, where possible, the data should be broadcast back to earth in real-time.

2) Thruster firings/beam operations: specific experiments to observe the results of thruster firings or, if available, charged particle systems should be developed. As was learned from SCATHA, such operations can induce rapid plasma variations.

3) EMI events: if the ESD/EMI detectors on IMPS report peculiar activity, such events would be logical candidates for quick analysis.

4) Contaminant releases: past Shuttle flights have indicated that there can be significant changes in the Shuttle-induced environment over short periods.

5) Major changes in Shuttle orientation: changes in Shuttle attitude relative to its velocity vector, the sun, and the Earth's magnetic field can all generate interesting variations during the changes.

6) Movement of the subsatellite: real-time data analysis of the subsatellite location as it changes relative to the shuttle will help to indicate locations of interest for further study during the flight and for future flights.

Such real-time analysis will require the principal investigators to commit to a rigorous schedule during flight. Even so, as evidenced by previous Skylab and Shuttle flights, the ability, based on real-time data, to reconfigure the experiments is crucial. An integral part of the program should be a data management system capable of handling real-time needs.

Within the first year following (and in the months preceding) launch, a series of data workshops should be organized on the lines of the NASA Goddard CDAW's (Coordinated Data Analysis Workshops). At these workshops, the IMPS data will be made available through the data management system so that the experimenters could rapidly compare their results. This approach argues for a central processing unit such as a dedicated VAX and a number of interconnected terminals. By the IMPS launch time (1987-88), such systems should be common. By the time of the later launches, such facilities and procedures will be standard. By limiting each workshop to a key topic, it should be possible to generate a report concentrating on that topic as the output of the workshop. These reports should be directed toward improving the relevant MIL-STDs and guidelines.

A major conference, such as was held in 1983, should be timed to occur within one or two years of each IMPS mission. These conferences should represent the culmination of each mission and have several sessions devoted to summarizing the results. In particular the results from the ground test programs should be incorporated into the mission reports at this time. The output from these conferences should be comprehensive mission analysis reports.

Based on the conference reports and the workshop results, the updating of the MIL-STDs and Guidelines should begin in earnest. A time table, spanning the two decades of the IMPS missions, should be established for updating these documents. These updates represent the primary goal of the IMPS program and should be given the highest priority of any items considered thus far.

5.1.6 Summary

The steps necessary for taking the IMPS and its companion missions from concept to utilization have been documented in this section. The major value of this presentation is that it organizes the IMPS mission into a logical sequence of events. It should be remembered, however, that the steps

overlap and repeat. Even so, the progression is clear and will be valuable for future planning efforts.

5.2 THE AURORAL/POLAR CAP ENVIRONMENT AND ITS IMPACT ON SPACECRAFT PLASMA INTERACTIONS

After the geosynchronous environment, which has been studied extensively over the last decade, the Earth's polar and auroral environments at Shuttle altitudes pose the greatest risks to future space systems. The objective of the JPL science support study has been to review the capabilities that currently exist to predict the Shuttle auroral/polar environments for IMPS and to compare these predictions with similar ones for the equatorial environment. The study was only concerned with the environment at 400 km over the northern hemisphere during winter. The results presented here are further restricted to periods of high solar (sunspot number, R, of 100) and geomagnetic activity (geomagnetic activity level, K_p, of 6_0). The emphasis here is on the set of models necessary to adequately specify the IMPS environment. Listings of the actual models, data for other locations and conditions, and references to models are not covered in t e report but can be obtained directly from JPL. For comparison, a table of values of the induced environment near the shuttle is also included (Table 5-2).

The JPL study also determined the relative importance and sensitivity of different types of interactions as a function of the environment. To accomplish this, where possible, the modeled environments have been used to predict the level of the anticipated interaction. Although this has proven to be a valuable output from the study, the interactions models employed were, of necessity, quite simplistic so that the absolute levels predicted are not intended to be accurate. Rather, the results demonstrate potential parameter sensitivities and areas where the environmental models need to be improved for IMPS.

TABLE 5-2. INDUCED ENVIRONMENT NEAR LARGE SURFACES IN SPACE[a]

Parameters	Ram	Wake	Comment
Neutral density, torr	10^{-5}	10^{-7}	Measured
Plasma density, cm^{-3}	As high as 5×10^{6}	As low as 10	Measured
Plasma waves	20 Hz - 300 kHz ($22V/m^{2}$/MHz at peak)	Low	Measured electrostatic waves
Energetic particles	Mean energy of electrons: 10-100 eV Flux: $10^{8}/cm^{2}$ sec ster eV Mean Energy of ions: 10-30 eV	Low	Higher fluxes predicted; little numerical data published
Glow, photons $(cm^{3}s)^{-1}$	10^{7} - 10^{8}	Low	Glowing layer in Ram 10-20 cm thick

[a]Reference: H. A. Anderson, Induced shuttle environments, IMPS ESWG minutes, February 14-15, 1984.

5.2.1 The Neutral Atmosphere

The major environmental factor at Shuttle altitudes is the Earth's ambient neutral atmosphere. Whether through drag or interactions with atomic oxygen, the effect of the neutral atmosphere (predominately the neutral atomic oxygen) on the spacecraft dynamics and surfaces greatly exceeds any of the other effects. There exist a number of models of the Earth's neutral atmosphere based on differing mixes of data and theory. The three main sources of data at Shuttle altitudes have been neutral mass spectrometers, accelerometers, and orbital drag calculations. Most models attempt to fit observations with an algorithm that includes the exponential falloff of the neutral density, the effects of increasing solar activity (particularly in the ultra-violet), the local time, and geomagnetic activity. Of these, the large variations associated with increasing geomagnetic activity (and subsequent heating of the atmosphere) have eluded adequate modelling by this fitting process. Unfortunately, it is clear from many sources that these variations, particularly in density, over the auroral zone often dominate the neutral environment. To date, no adequate method of including these effects in the models has been devised. (Some recent, very sophisticated theoretical computer models do hold promise, however.)

Two models were used in the IMPS study to compute the variations in drag due to the neutral atmosphere at 400 km. These are the Jacchia 1972 model and the MSIS model. These models are readily available in computer format and have been well-developed over the last decade. For the purposes of this report, the Jacchia 1972 model results are presented. (The MSIS model results deviate by about 20 percent from the Jacchia values on the average. This amount constitutes a relatively small value, given the much larger average uncertainties in the models themselves). Figures 5-1a, 5-1b and 5-1c illustrate the type of output obtained in the Jacchia 1972 model. The results are for the northern hemisphere (i.e., looking down on the north pole with the projection in terms of equal latitude intervals) and 400 km. The geomagnetic conditions are for F10.7 = 220 W/m^2

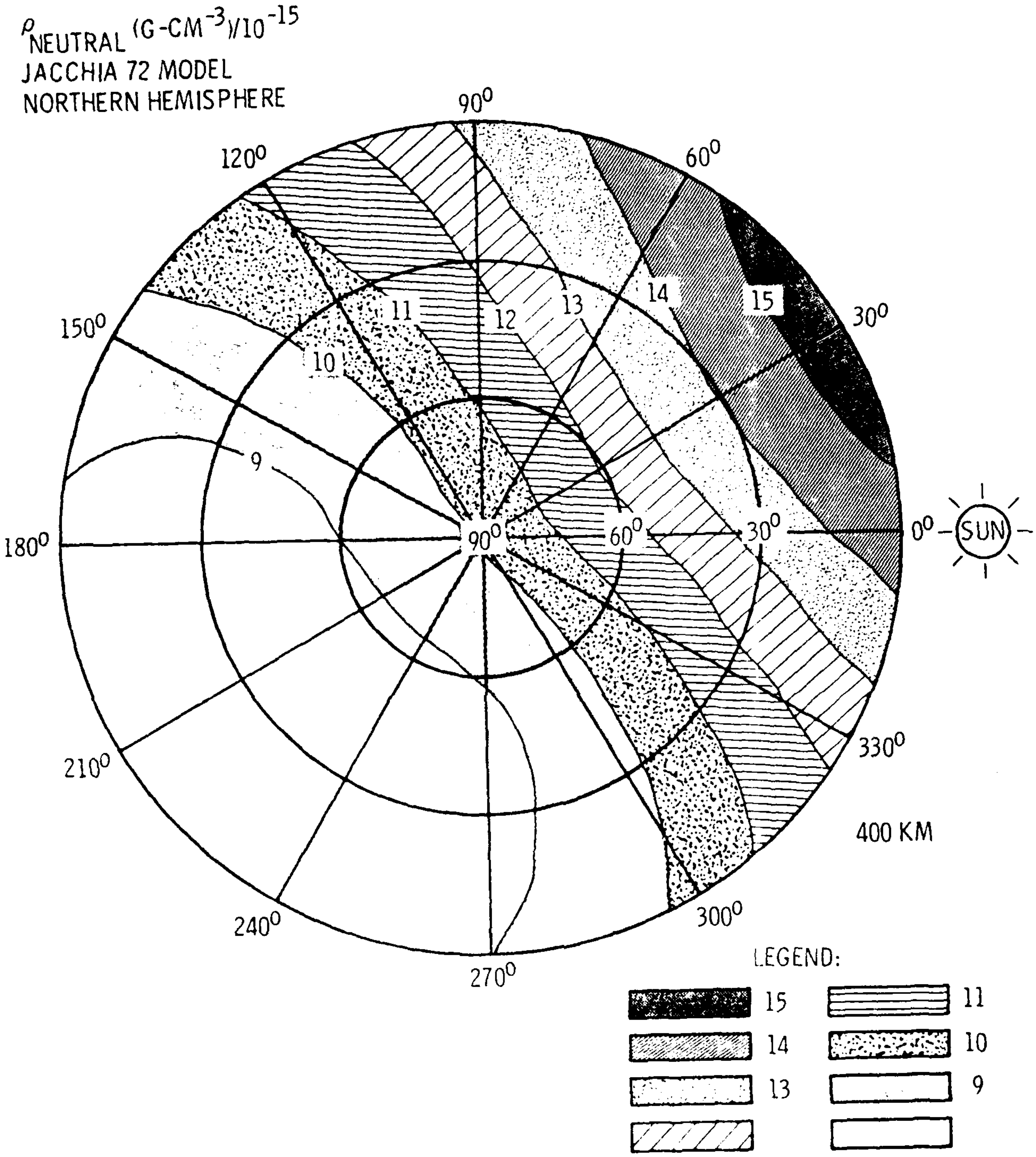


Figure 5-1a. Neutral Density for the Jacchia 1972 Model in Units are of $g\text{-}cm^{-3}$ -10^{15}

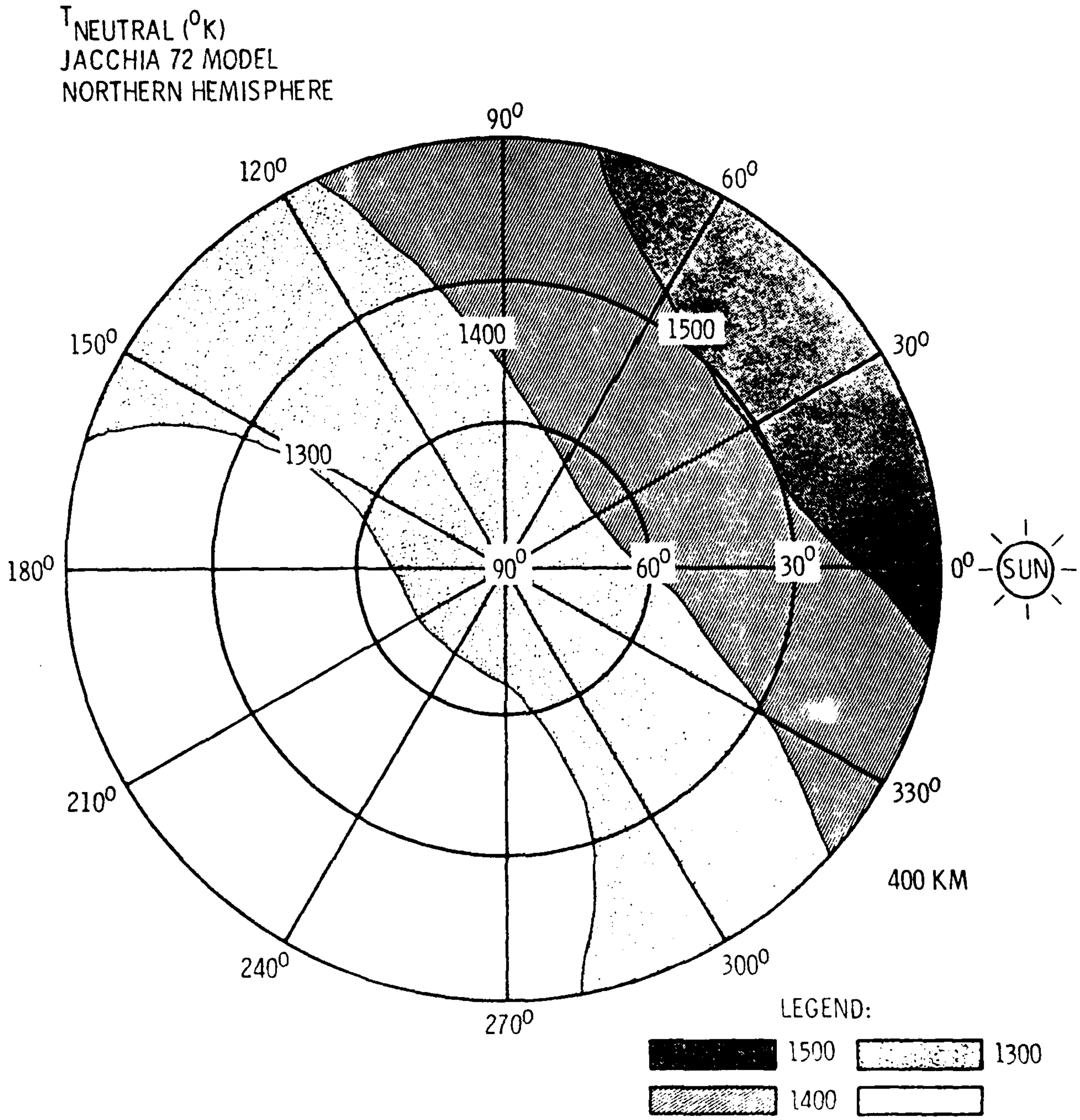


Figure 5-1b. Neutral Temperature for the Jacchia 1972 Model in °K

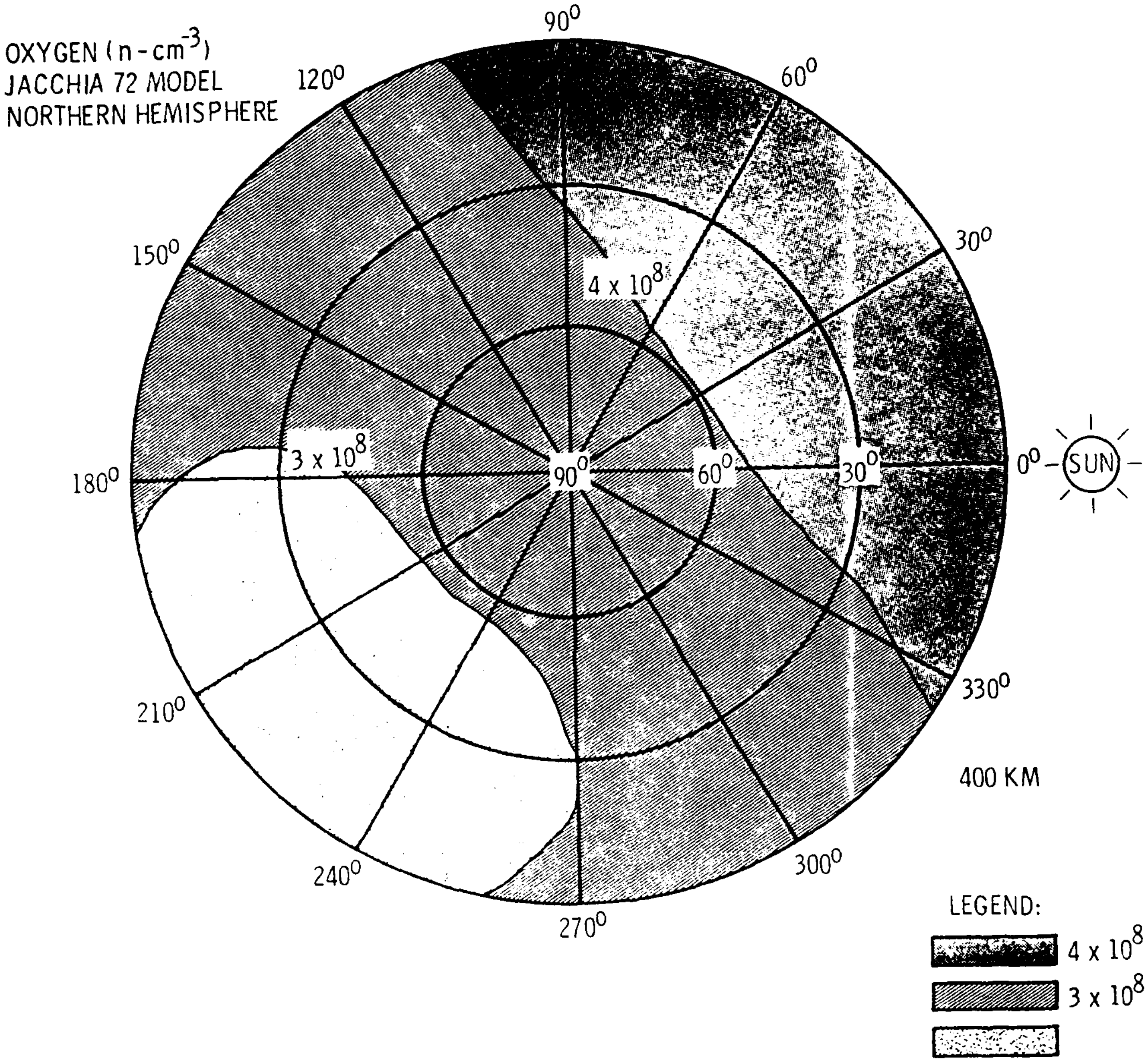


Figure 5-1c. Number Density of Oxygen for the Jacchia 1972 Model in cm^{-3}

(the solar radio flux at a wavelength of 10.7 cm) and Kp = 6_0. These conditions yield an exospheric temperature of about 1500 ^oK.

Several features are apparent in the Figures. First is the two-fold increase in density from midnight to noon. Further, there is the pronounced shift by 2 hours from the peak in the density and temperature maxima away from local noon. This well known phenomena results from the rotation of the earth and causes the peak in atmospheric heating to occur after local noon. The Figures show no clear features associated with the auroral zone. This is due to the averaging used in deriving models of this type, which smooths out the density waves normally observed over the auroral zone. Even so, the model results are useful in estimating the levels of atmospheric drag and, when the processes become better known, also the levels of Shuttle "glow" and surface degradation.

The major effects of the neutral atmosphere at 400 km result from the impact of neutral particles on spacecraft surfaces. This impact causes drag and surface damage. The standard expression for the drag force is formulated as:

$$F(drag) = 1/2 \quad V^2 \; CD \; A = \\ = \; (300 - 5000) \text{ dynes} \qquad (1)$$

where:

$= 10^{-15}$ g/cm^3

CD = drag coefficient = 2.2 - 4.0

A = cross-sectional area of spacecraft

= 50 m^2 (Frontal) for Shuttle

= 400 m^2 (Base) for Shuttle

V = spacecraft velocity

= 7.6 km/s

It is evident that uncertainties in the orientation of the Shuttle and lack of knowledge in the drag coefficient are equal to or greater than variations in the neutral environment at these altitudes. Given, however, the uncertainty in the effects of auroral heating, there could be an additional factor of 10 in the element of uncertainty contained in these drag calculations.

5.2.2 Magnetic Field

For the purposes of this study, the POGO model has been used in conformance with the International Reference Ionosphere (IRI) model. This model is an expansion of the Earth's magnetic field in terms of spherical harmonics. According to this model, the total magnetic field magnitude at 400 km is represented in Figure 5-2a. The surface field is observed to vary from a minimum of 0.25 G near the equator to 0.5 G over the polar caps, as shown in Figure 5-2a. The existence of two peaks in the magnitude is real, reflecting the complexity of the magnetic field in the auroral/polar cap regions. Geomagnetic storm variations are typically less than 0.01 G so that during a severe geomagnetic storm, magnetic fluctuations will be small compared to the average field - - a marked contrast from the atmospheric and ionospheric environments. Even so, the great complexity of the magnetic field over the poles makes it difficult to use magnetic guidance systems in these regions - - a fact long known to AF navigators.

In addition to magnetic torques (which are system dependent), the Earth's magnetic field can induce an electric field in a large body by the vxB effect as represented below:

$$E = 0.1\ (v \times B)\ V/m = 0.3\ V/m \tag{2}$$

where:

v = spacecraft velocity
= 7.6 km/s
B = 0.3 G

Since the Shuttle's divisons are roughly 15 m x 24 m x 33 m, potentials of 10 V could be induced by this effect. As systems grow to 1 km or large, the induced magnetic fields will grow correspondingly.

As shown in Figure 5-2b, the induced electric field for a vehicle of 90^{o} inclination has been calculated. As anticipated, the largest electric fields will be detected over the polar caps. The ambient environment can also produce strong electric fields in the auroral/polar regions. Although not

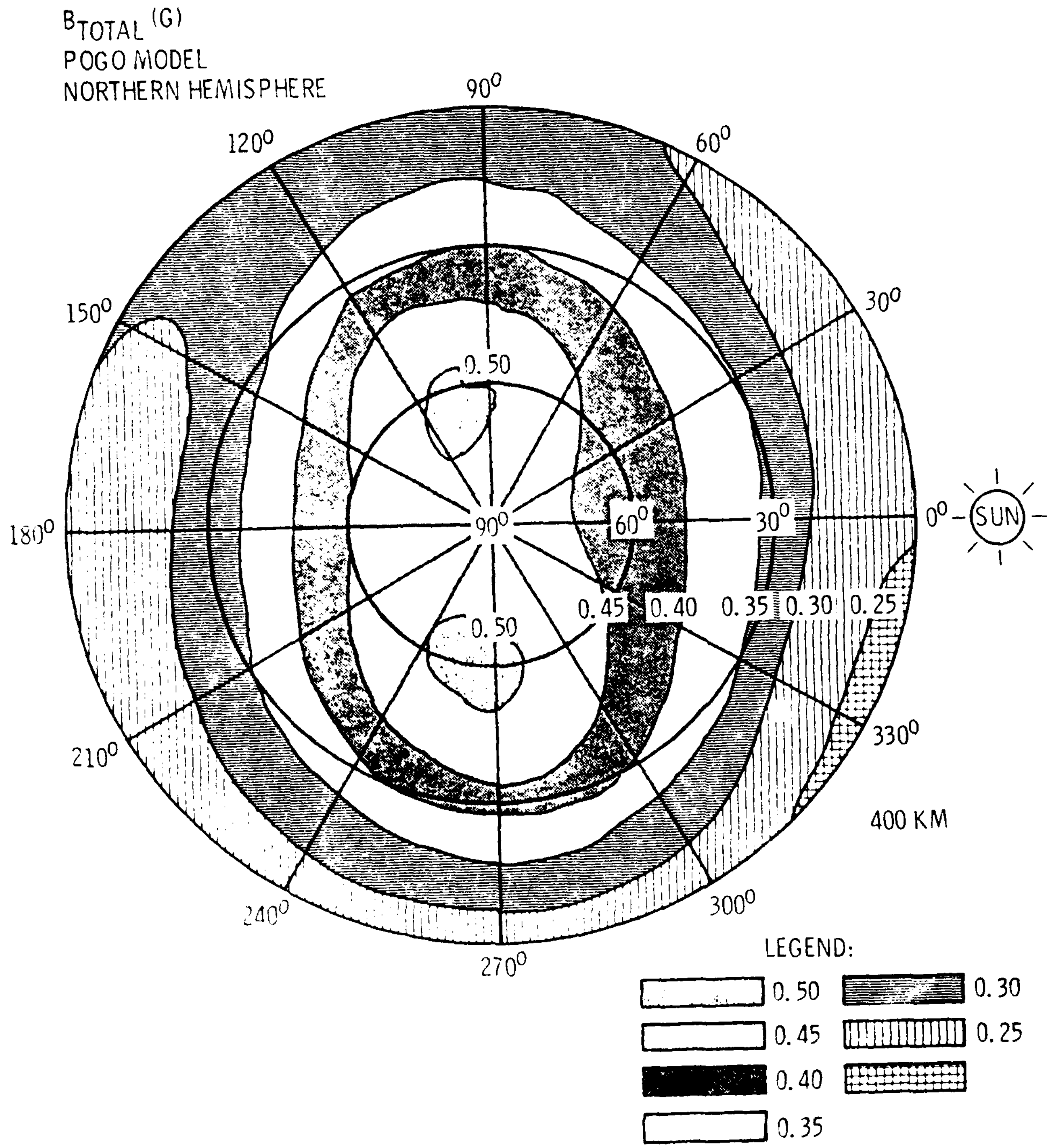


Figure 5-2a. Total Magnetic Field at 400 km for POGO Magnetic Field Model. Units are G

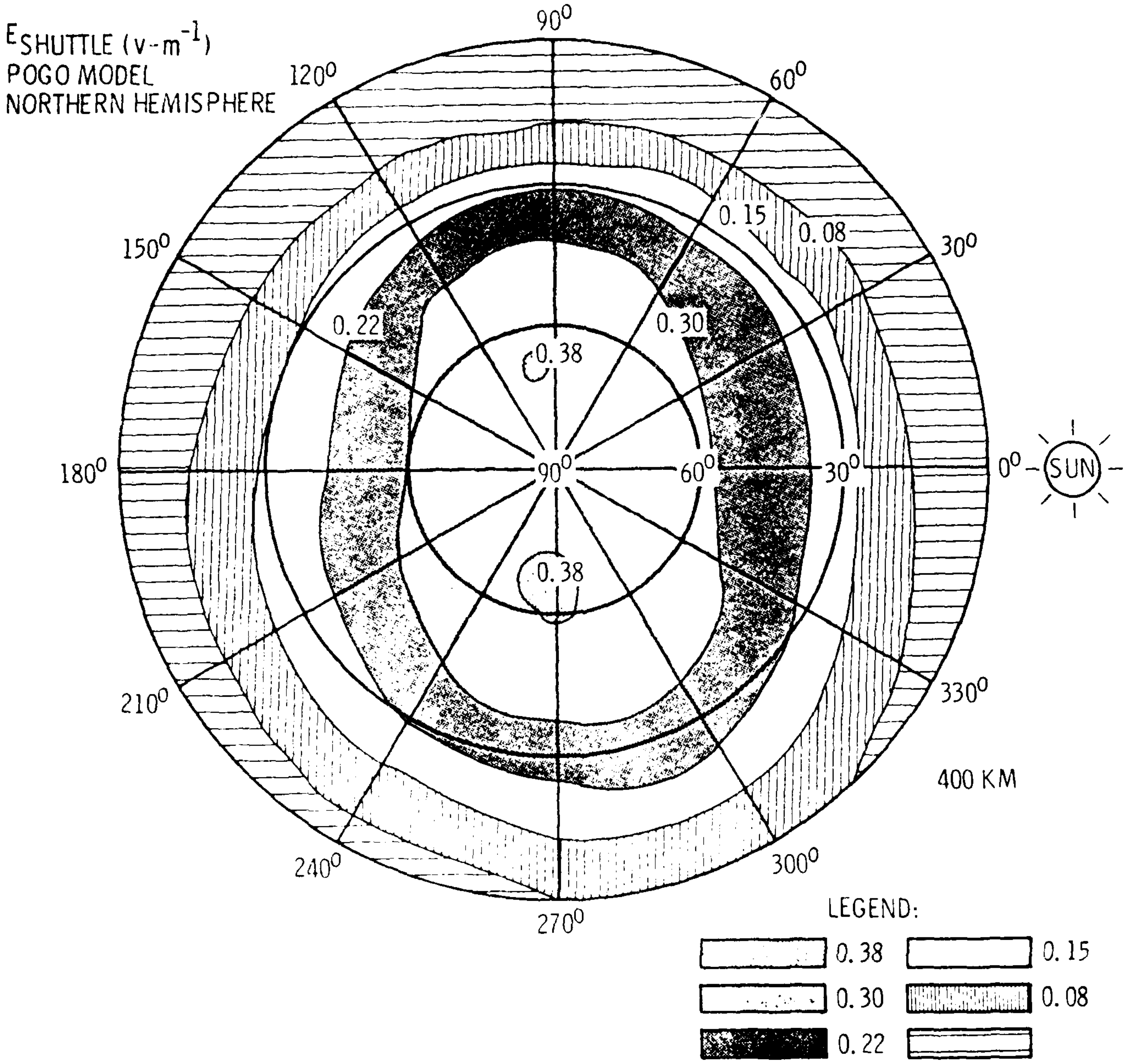


Figure 5-2b. Absolute Value of the vxB Electric Field Induced on a Body in a 90° Inclination Orbit for the POGO Model. Units are V-m^{-1}

included in Figure 5-2b, these fields can reach values of nearly 100 mV/m (Reference 7), a sizable fraction of the induced field. These fields are also comparable to the fields necessary to deflect charged particles in this environment, since the particles have ambient energies of typically 0.1 eV Ram energies for the ions like oxygen ions. These ions can reach energies of several eV, and must, therefore, be taken into account when studying ionospheric fluxes.

5.2.3 The Ionosphere

Unfortunately, relatively few ionospheric models are presently available, and most of these only predict electron densities - - the most readily measureable quantity by ground means and the most important to radio propagation. The principal ionospheric model based on observations now available is the International Reference Ionosphere. This is the only readily available computer model that provides the electron and ion composition and temperature as a function of longitude, latitude, altitude (65 to 1000 km), solar activity (by means of the sunspot number, R), and time (year and local). Although the model is limited (it is confined to R values of 100 or less, whereas R values of 200 may occur during solar maximum), it is the "best" available comprehensive model of the ionosphere.

Figures 5-3a, 5-3b and 5-4, present output samples from the IRI model for the northern hemisphere. Figure 5-3a presents the electron number density and temperature at 400 km for R=100 in December. Unlike the neutral temperature, the electron temperature increases by a factor of 2 in going from the equator to the pole as shown in Figure 5-3b. Like the neutral density, however, the peak in the electron density is shifted by about 2 hours from local noon.

At an altitude of 400 km, the ionosphere is dominated by oxygen ions, primarily because of the corresponding high level of neutral oxygen. Values for oxygen are presented in Figures 5-4a and 5-4b. The temperature profile is the same for all ion species in the IRI model and cannot, for

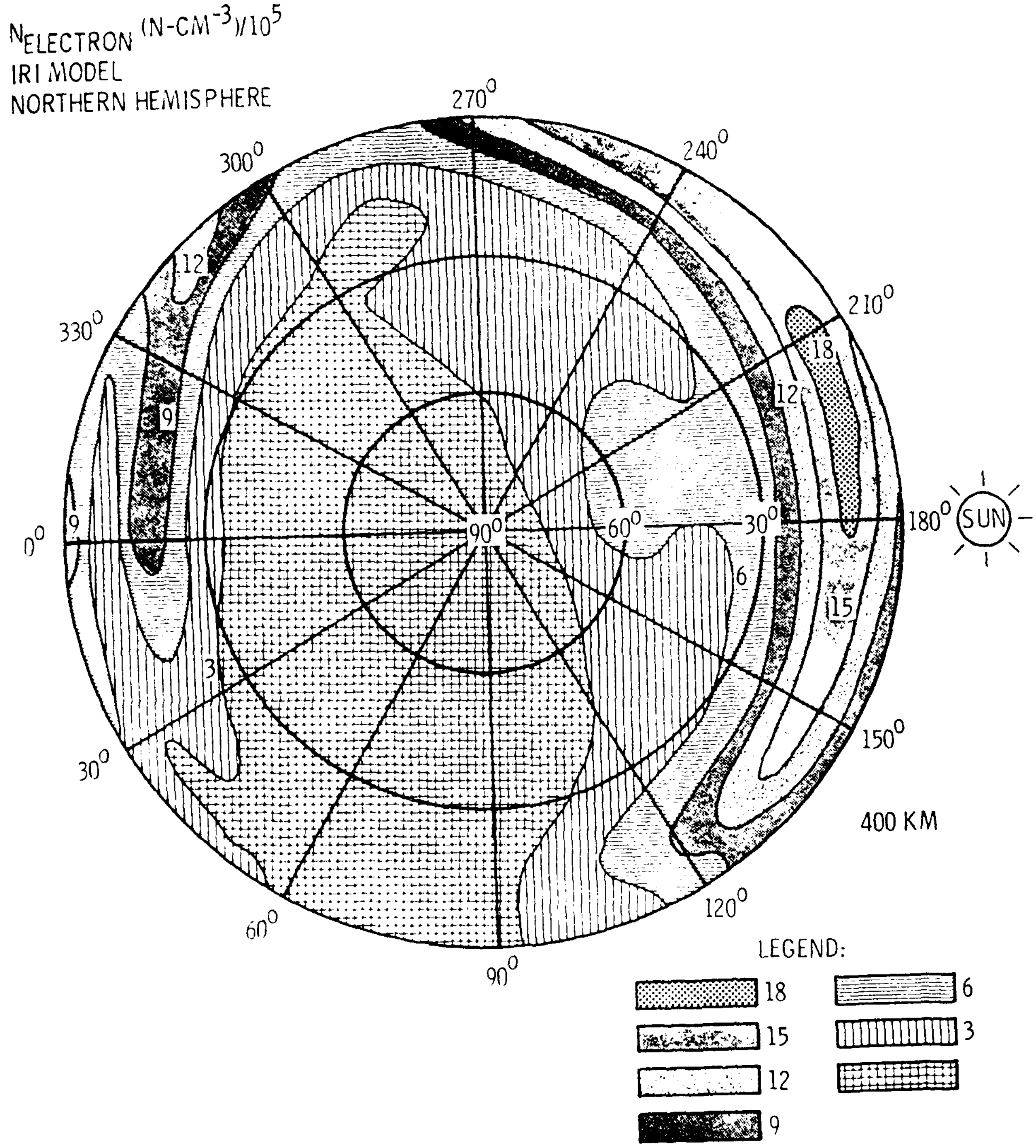


Figure 5-3a. Electron Density at 400 km as predicted by the IRI Model. Units are cm^{-3}-10^5

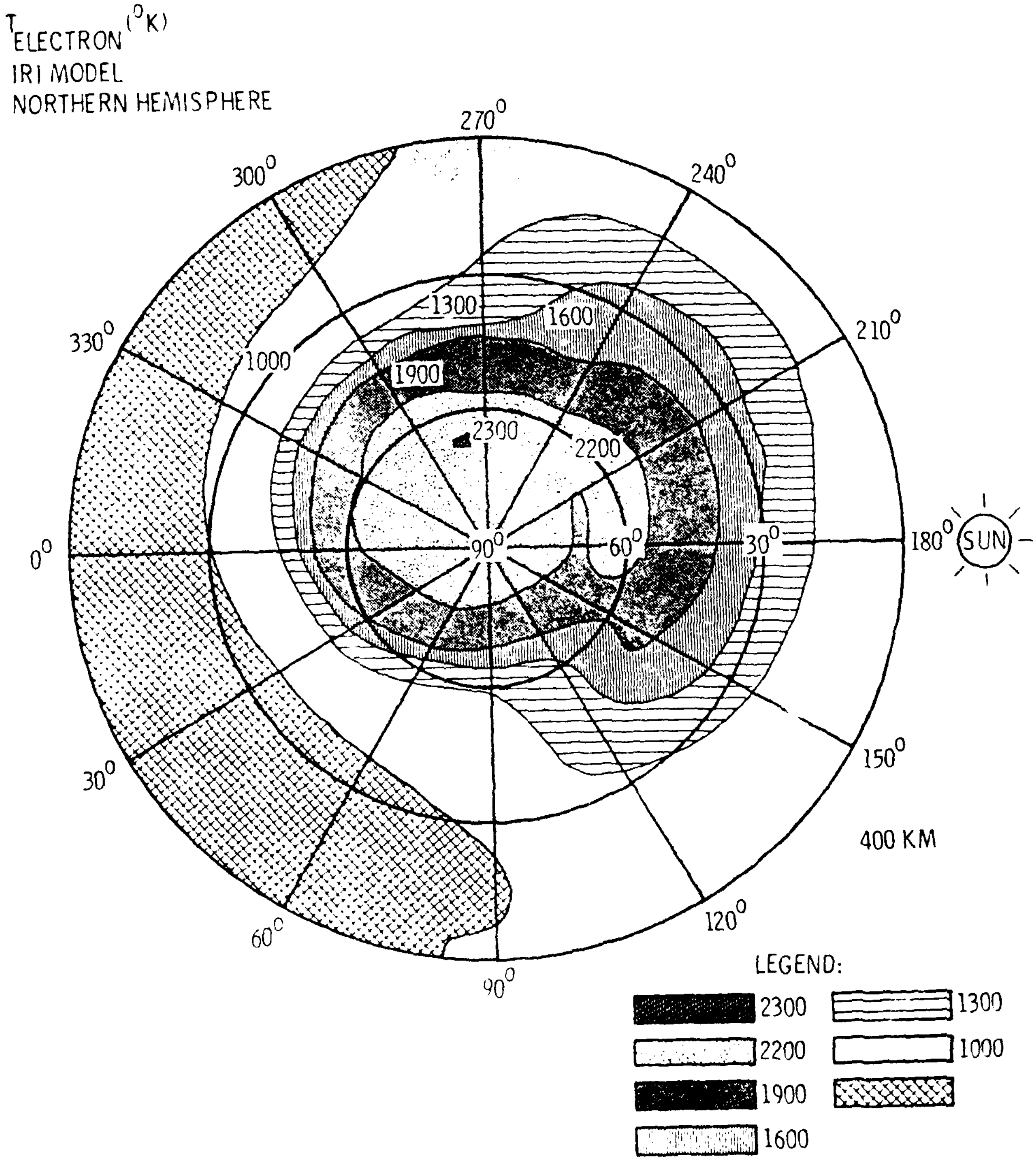


Figure 5-3b. Electron Temperature at 400 km as predicted by the IRI Model. Units are °K

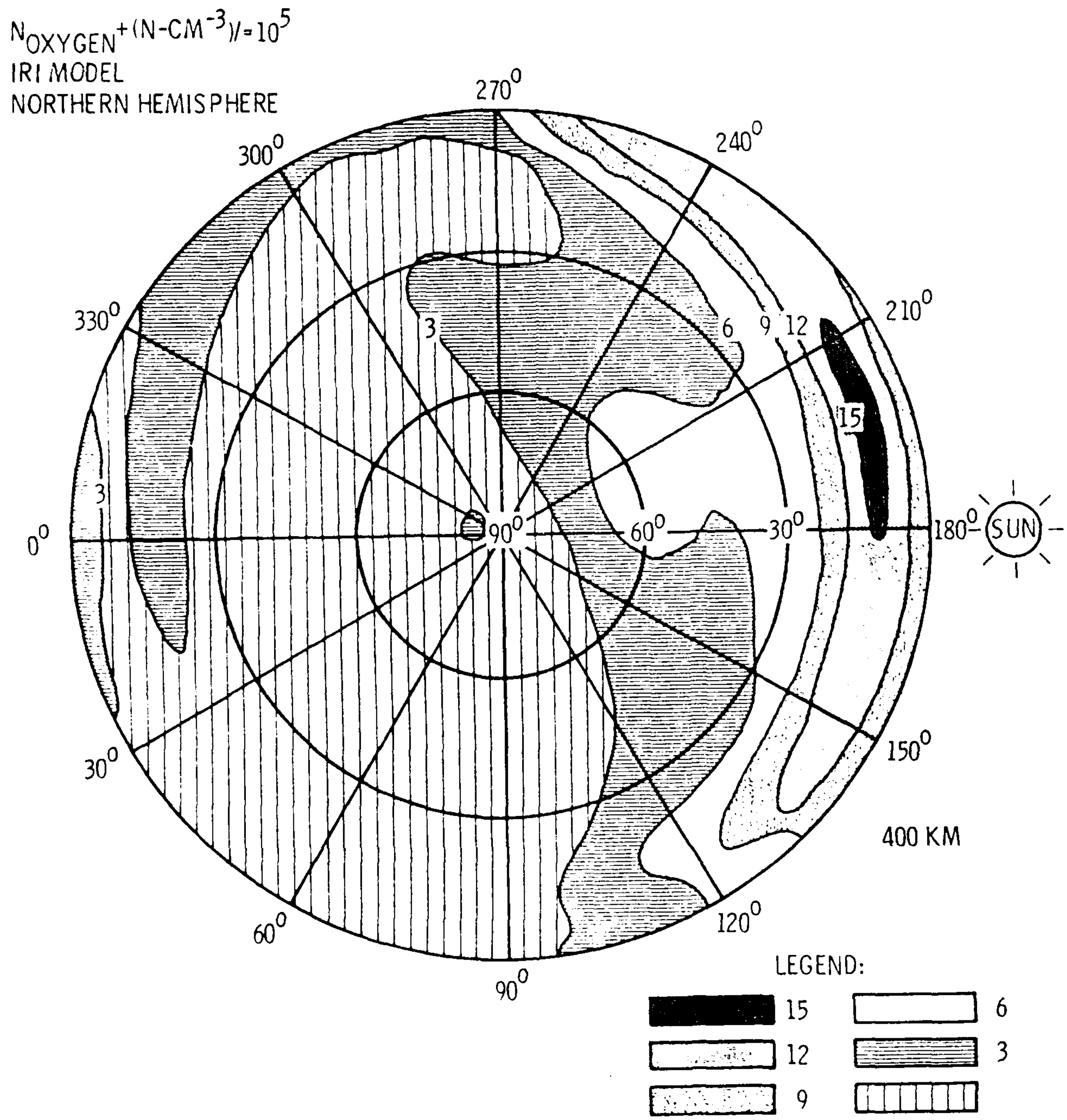


Figure 5-4a. Oxygen Ion Density at 400 km as predicted by the IRI Model. Units are cm^{-3}-10^5.

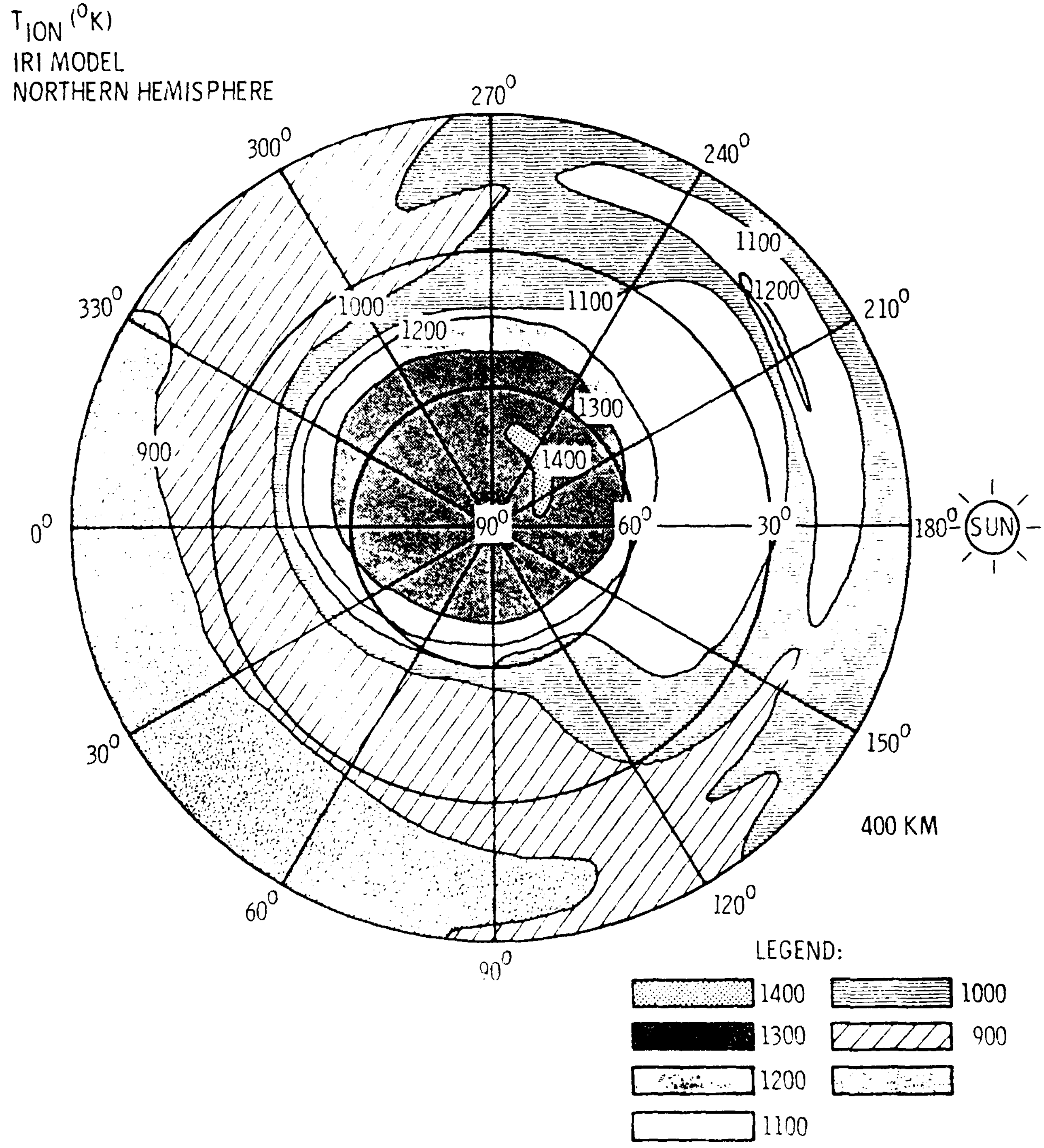


Figure 5-4b. Oxygen Ion Temperature at 400 km as Predicted by the IRI Model. Units are °K.

physical reasons, exceed the electron temperature. Unfortunately, at 400 km for R=100 or larger, the IRI model will occasionally predict ion temperatures far in excess of the actual electron temperature. This is because the model is based on a limited set of data (R 100) and needs improvement. Theoretical models exist that avoid this problem, but these models are still too cumbersome to be run on all but the largest computers.

Using a simple one-dimensional, "thin sheath" ram model for ion collection, Figure 5-5 shows potentials for the case of no secondary emission and no photoelectron current, whose calculations were based on Figures 5-3a, 5-3b, 5-4 and 5-4b. The spacecraft-to-space potential varies from -0.2 V at the equator to -0.7 V at the pole - -, in rough agreement with observations. Thus, based on the IRI model environment alone, spacecraft charging is not a concern (note: the high plasma density will encourage plasma interactions with exposed high potential surfaces).

5.2.4 Auroral Environment

The most dramatic changes in the Earth's environment at Shuttle altitude are brought about by geomagnetic substorms. In this section, a sample auroral flux model based on data provided by the Air Force Geophysics Laboratory (courtesy M. Smiddy and D. Hardy) is used to estimate these effects. The data were provided in the form of 7 sets of color contour plots of the electron number flux and energy flux in intervals of K_p from 0_o to 6_o. The plots were crudely approximated by a simple analytic function in geomagnetic local time and latitude and the geomagnetic K_p index. Although, the AFGL data were for about 800 km, no attempt has been made to correct for altitude in this model.

The sample auroral flux model was used to estimate the auroral/polar cap electron temperature and number densities. The results for the northern winter hemisphere and a K_p of 6 are shown in Figures 5-6a and 5-6b. The results imply that there is a peak in the density of the auroral electron flux of about 1000 cm^{-3} in the noon sector (Figure 5-6a), while the auroral electron temperature is 1 keV in the post-midnight sector (Figure 5-6b). Although the validity of this crude result is dubious, it needs to be

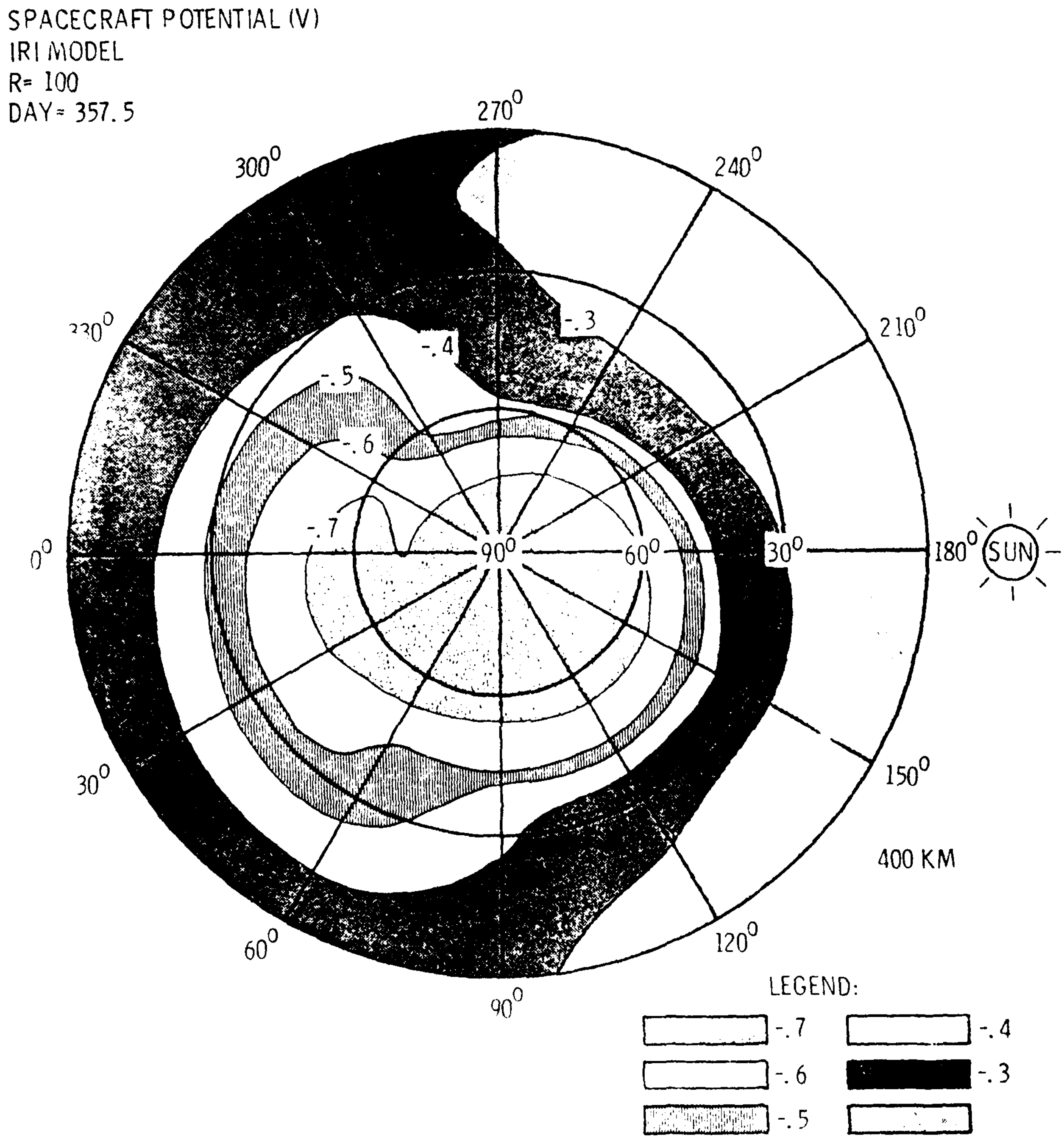
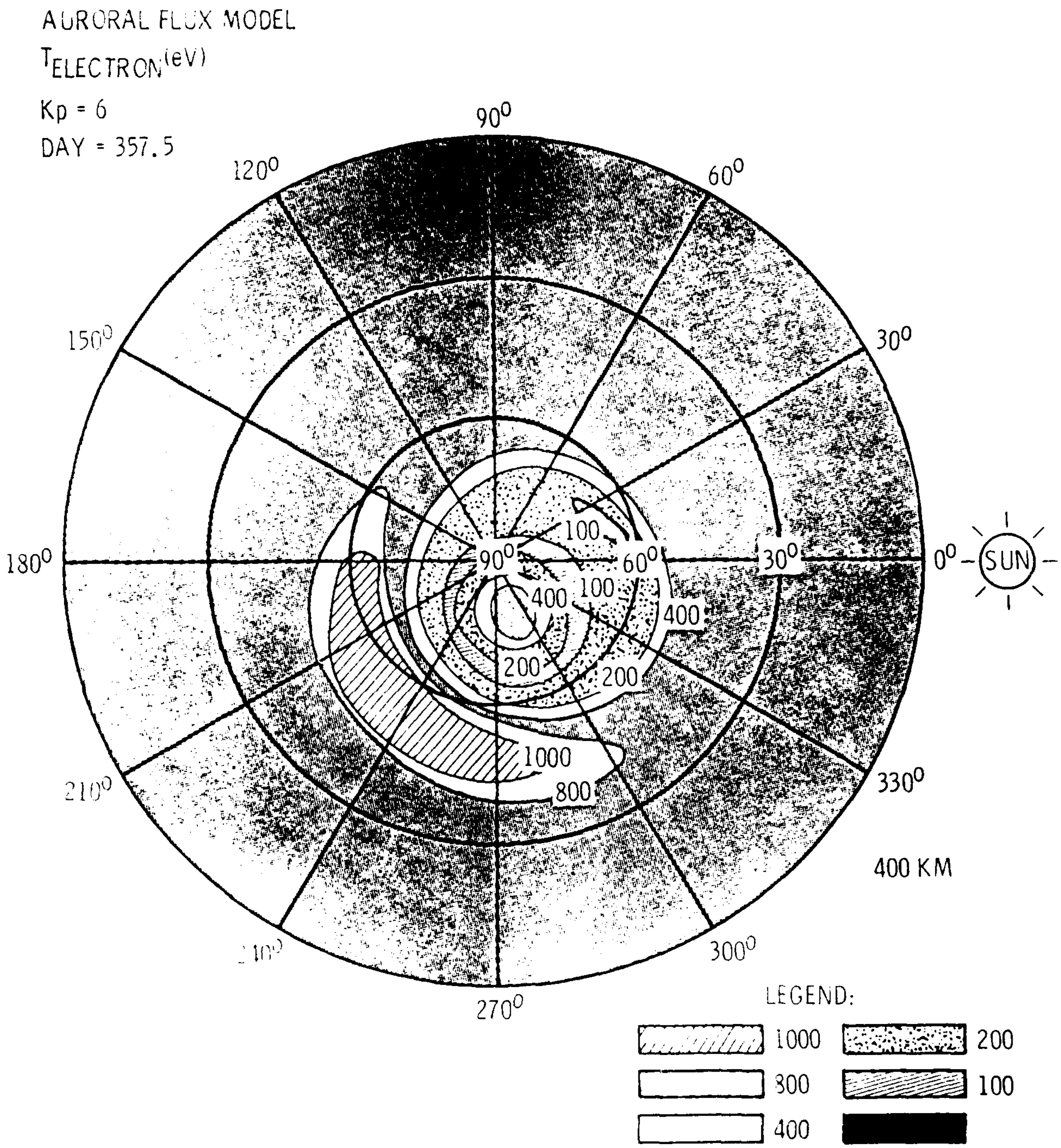


Figure 5-5. Polar View of the Spacecraft-to-Space Potentials Predicted for the IRI Model.



[illegible] Temperature of the Auroral [illegible] Flux at 400 km. Units are eV.

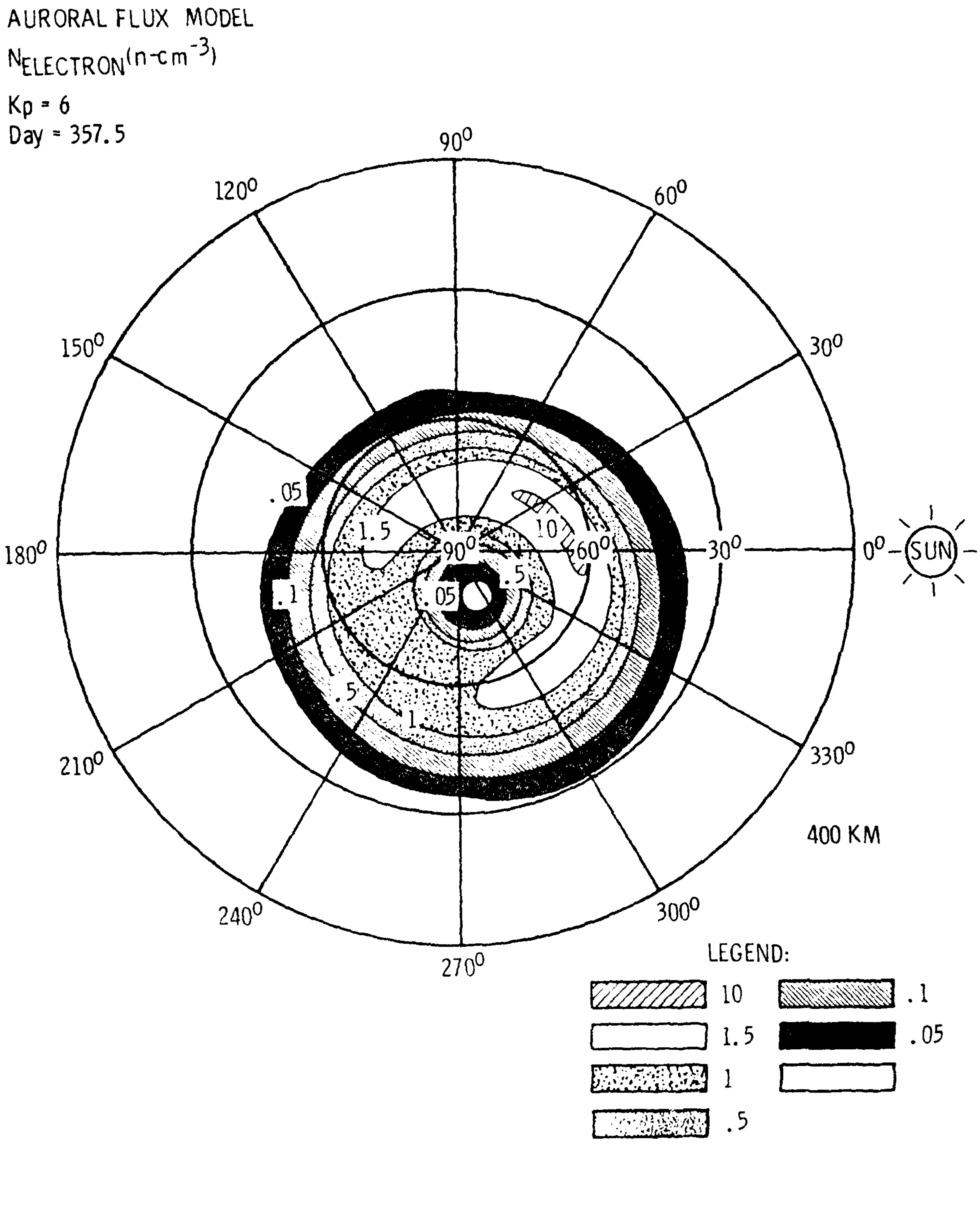


Figure 5-6b. Density of the Auroral Electron at 400 km. Units are $n\text{-}cm^{-3}$.

compared with the actual AFGL data when they become available. The range of values should at least be indicative of the characteristics of the average auroral fluxes (comparisons with other data sources bear this out).

The results in Figures 5-6 were used in conjunction with the IRI data at 400 km in order to estimate the expected variations in spacecraft potential in the auroral zone and over the polar caps (the auroral ion fluxes do not contribute significantly to the ambient ion current, so that their exclusion should not seriously alter the results). There was little or no change from the results obtained in Figure 5-5. This is not surprising, since the average auroral flux levels seldom exceed the ambient ion and electron ionospheric fluxes.

In order to estimate which auroral flux levels are necessary to bring about significant increases in the spacecraft potential in the auroral/polar cap regions, the electron density and temperature in Figure 5-6 were increased by 10. This significantly increased the potential - - raising it from a few tenths of a volt negative to several thousands of volts in the early afternoon sector. These results are illustrated in Figure 5-7. Such a large increase in the auroral flux may indeed occur over narrow regions in the auroral zone, but the details of the assumed charging model greatly affects the results. Specifically, if a 1-dimensional, thin sheath model is assumed, the auroral potentials will reach -6000 V once the ion return current is equated with with the cold ambient ion current. If the ion return current is assumed to be the ram current, as is assumed here, the potential is about -1200 V maximum (which is probably the more "realistic" assumption). If, on the other hand, the ion return current in the charging model is assumed to be for a thick sheath, orbit limited case, such as assumed at geosynchronous orbit, the potential is only -1 to -2 V! This sensitivity problem to the details of the amount of return current is expected, given the simplicity of the charging model. Its resolution will need to await the development of more accurate charging models for the conditions at Shuttle altitudes.

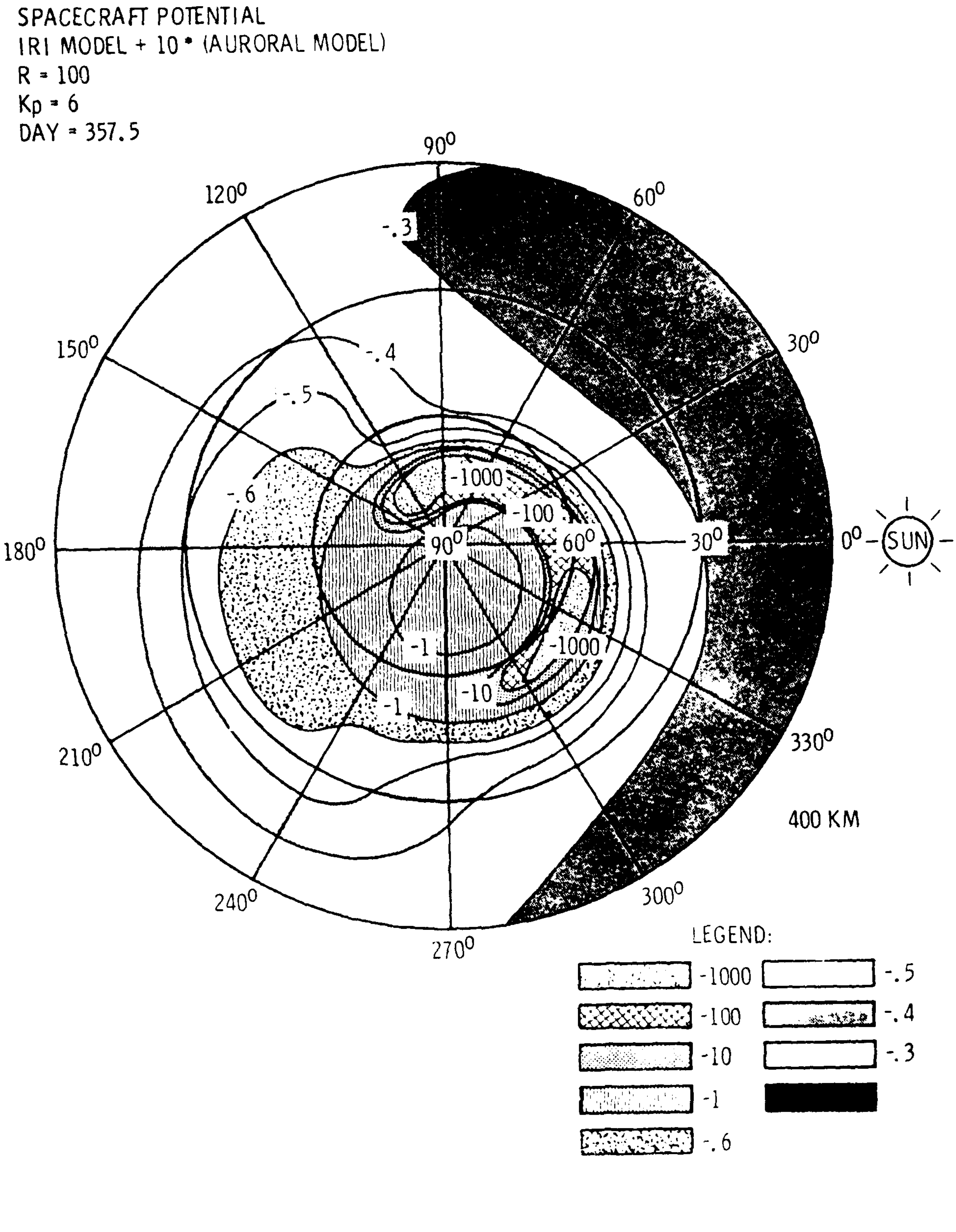


Figure 5-7. Polar view of the spacecraft to space potentials predicted for the combination of the IRI and auroral models.

5.2.5 Conclusions

The JPL study has brought together most of the elements needed to form a complete model of the ambient IMPS environments. Emphasis has been placed on modeling the interactions in the auroral/polar cap regions where, although models of the average ambient environment (neutral particles, fields, iono- spheric particles, and auroral/polar cap fluxes) are satisfactory for many study purposes, the intense variations in the auroral zone are not adequately modeled. These variations are known to exist from in-situ observations and to result from an increase of several orders of magnitude the charged particle fluxes and atmospheric heating which can alter the neutral composition. It is only recently that long-term statistical studies and examples of extreme cases have become available. In the near future, it is anticipated that models of the environment will become increasingly sophisticated and capable of being used in modeling effects such as spacecraft charging which will be much more accurately presented, compared with the accuracy than here. Even so, the JPL results should assist current IMPS studies in better assessing the average levels of effects in the auroral/polar regions, and in comparing equatorial and auroral/polar environments. The process of presenting the models has also indicated where improvements need to be made in the existing models. This is particularly true in the case of the auroral model, in view of the varying sensitivities of the principal interaction to changes in the ambient environment (i.e., spacecraft potential calculations).

5.3 GROUND TEST PLAN

A major consideration for the IMPS mission is that of a ground test program will be executed in conjunction with the actual flight(s). Aside from the obvious requirements for preflight calibration and payload integration testing, IMPS can be tested postflight, because of the inherent "returnable" nature of Shuttle missions. The intent of this subsection is to describe in general terms a ground test program that will enhance the usefulness and increase the understanding of the IMPS obtained data*.

*This subsection has been summarized from the Science/Engineering Final Report.

5.3.1 Preflight Testing

Several examples are presented in this subsection that illustrate the value of ground testing in preflight planning for the evaluation of the IMPS data return. The major thrust in planning ground testing is that the instruments planned for IMPS will also be of value for studying space interactions in general, both on the ground and in space. Pursuant to this concept, the Shuttle flight becomes an extension of the laboratory rather than a separate entity.

In the first example, the DME and PASP instrument package could be used prior to launch in conjunction with plasma simulation studies for characterizing arcs and plasma noise. This will simplify the classification of arcs during the mission. The instrumentation will also be placed in the flight configuration and used to refine the arc location technique proposed for the flight.

In the second example, the DME will be employed to catalog Shuttle material properties prior to the first mission. Not only will this test significantly enhance the data return from the flight but will also be of general value in understanding Shuttle materials and how they interact with the environment - - currently a topic of very real concern. This information is doubly important since, to date, laboratory efforts at characterizing spacecraft charging proper- ties have been minimal.

5.3.2 Postflight Ground Testing

In addition to the preflight tests described above, there are unique postflight ground test opportunities afforded by the IMPS mission. Principal among these are the opportunities to recalibrate the instruments and test assumptions about how an event has occurred by conducting chamber simulations with the actual flight hardware. In particular, if an arc was postulated to have occurred at a specific point and to have, as a result, certain electrical characteristics, it would be feasible to test such

assumptions by setting up the configuration, synthesizing the arc source, and comparing the results with the original observations. Ideally, such an experiment will permit an unambiguous test of the assumptions.

Material samples can be retested to determine the effects of the space environment on their properties. If the materials are properly handled, the effects of re-entry can be studied systematically. Testing of small portions of the Shuttle itself prior to launch and after return would be of additional value. As already noted, several of the IMPS instruments are capable of accomplishing this testing. Additional testing using standard laboratory equipment would complement these studies. This latter type of testing would be valuable in determining the actual sensitivities of the IMPS instruments.

A final type of postflight testing that would be of value is that involved in reconfiguring the system. The initial flight, in any series, always indicates ways to improve the basic design. With IMPS, as it is intended to be reflown, the recovery of the payload will permit rapid redesign. Testing of the new payload will benefit from the flight data and the postflight ground testing. Given better knowledge of the effects considered critical, the reconfiguration testing can concentrate on those areas.

In Figure 5-8, a possible ground test schedule is presented that incorporates the ideas presented in the preceding text. The Figure is focused on the launch date and indicates prelaunch and postlaunch activities. Prelaunch experiment calibration and systems integration testing have been left out of the Figure, as these would be included in the detailed IMPS mission plan that accompanies this effort.

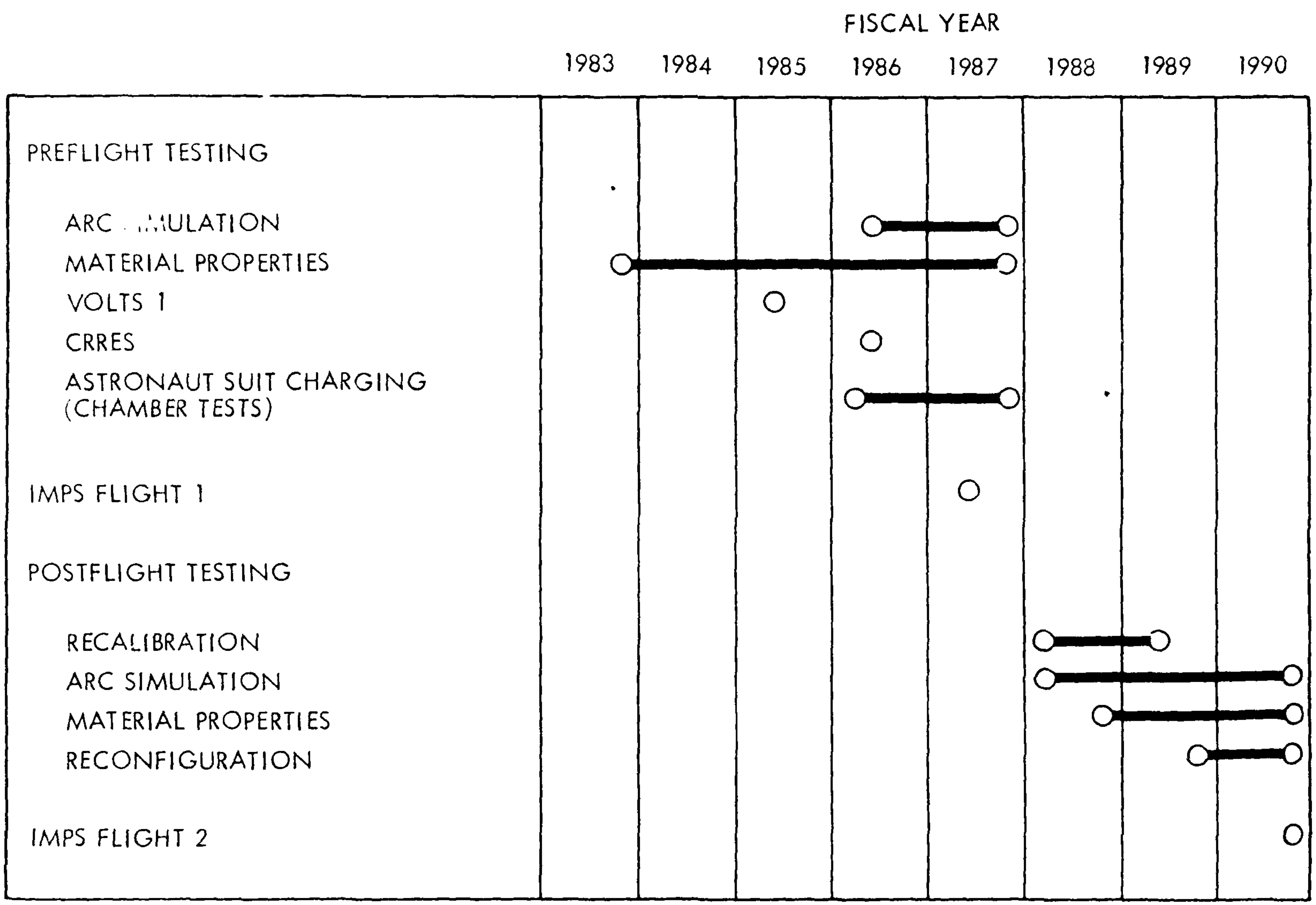
5.3.3 Ground Based Measurements

Numerous complementary observations. derived from ground testing, and apart from the IMPS itself, may be of great value to the mission.

Magnetometer, riometer, DMSP auroral photographs and electron precipitation measurements, all-sky auroral photographs, and other measures of the gross features of the magnetosphere during the mission, such as ground-based measurement, and incoherent scatter radar measurements, could be of obvious value and offer a particularly fruitful source of information on the ambient environment of IMPS. The possibilities implied by such measurements are explored in the following.

The polar ionospheric plasma is known to be characterized by considerable spatial and temporal variability as compared with lower latitudes due to the strong influences of convection electric fields and precipitating particles of magnetospheric origin. Even an instrumented subsatellite cannot provide unambiguous separation of the sources of variability of the measured disturbance zone" plasma characteristics. A preferred approach may entail a set of environmental sensors, arrayed along the length of a moveable or even a stationary boom. In any case, on the initial and future IMPS missions both of these options may be precluded, based on budgeting considerations. For this reason, the possible contributions of ambient plasma parameters as measured by incoherent scatter radars, should be closely examined. Incoherent scatter radars provide measurements of T_e, T_i, N_e, and plasma of drifts between nominal altitudes of 100-1000 km, thereby complementing the capabilities of satellites, in that they are capable of investigating temporal and sometimes spatial behavior from a fixed geographic location. It is, therefore, specifically recommended that Thomson Scatter ground support be included as part of the overall IMPS ground support plan to provide information on ambient plasma properties. as well as a context for interpretation of on-board IMPS diagnostics.

Table 5-3. Ground-Test Support Plan for IMPS



SECTION 6

RELIABILITY & QUALITY ASSURANCE

6.1 PROJECT SUPPORT

Reliability and Quality Assurance (R&QA) involvement began with the concept and proposal phase of the IMPS project. Support at the initial stages of development insured that R&QA concepts and design considerations became an integral part of design thinking, preventing the delays and cost of redesign at a later time.

6.1.1 Support Team

The IMPS R&QA team consists of the R&QA manager and members from the following areas: Reliability, Quality Assurance, Software Independent Verification and Validation, Environmental Requirements, and Electronic Parts.

6.1.2 Risk of Management Classifications

As it applies to other projects, the basis for R&QA support to IMPS involves risk management. The R&QA effort is directed toward obtaining as reliable a system as acceptable risk will allow, within project constraints. This risk is managed at JPL through the use of a system of payload classifications. These payload classifications, designated by each project, are defined in the NASA Management Instruction NMI 8010.1, "Classification of NASA Transportation System (STS) Payloads." The classifications, designated by each JPL project, are the basis for the reliability and quality assurance provisions, as identified in JPL Document D-1489, "Payload Classification Product Assurance Provisions."

The JPL Project Office has initially designated the IMPS instruments as a class C flight system, while the carrier has an initial classification of class B. Class C is defined as:

> Flight payloads for which reflight or repeat flight is planned as a routine backup in the event of in-flight soft failure, and reflight or repeat flight costs are low enough to justify limiting qualification and acceptance testing to end item environmental screening. (In addition to whatever is required for STS safety and compatibility and payload functional testing.) There is not significant intangible impact of soft failure except the cost and repair and reflight, or repeat flight which is estimable with reasonable confidence and is directly tradeable with in-flight reliability enhancement costs. Therefore, a decision criteria of minimum total expected cost is appropriate and practical.

Success-critical single failure points are acceptable. The qualification and flight acceptance program are limited to functional, environmental screening, safety, and interface compatibility tests. Class C is typified by Spacelab or Orbiter attached payloads.

Class B is defined as:

> Flight payloads for which an approach characterized by reasonable compromise between minimum risks and minimum costs is appropriate due to the capability to recover from in-flight failure by some means that is marginally acceptable even though it involved significantly high costs and/or highly undesirable intangible factors.

Success-critical single failure points are acceptable based on cost/risk trade-off analysis and measures implemented to minimize the risk. Single string design approaches are acceptable; however, payloads or experiments with multiple information sources should provide redundant functions to preserve the capability for partial success. The qualification and acceptance program is more extensive than functional or environmental screening tests. Class B is typified by free flyer type payloads that are accessible by the STS after deployment, but may not be retrievable.

The initial requirements/assessment of the IMPS instrument system and space system, as mentioned above, are based on the provisions of JPL D-1489 Payload Classification Product Assurance Provisions Document, and will be used to identify areas requiring further review. Final requirements assessments may be based on negotiated provisions. JPL D-1489 provides an interpretation of the criteria of NASA NMI 8010.1 for payload classification. As such, it sets forth the principal product assurance elements and specific provisions, as a function of payload class, within each element which is to be used by JPL in its classification of Space Transportation System (STS) and expendable launch vehicle payloads.

6.2 RELIABILITY AND QUALITY ASSURANCE - INSTRUMENT SYSTEM

The instrument system has been initially classified as class C. Table 6-1 lists essentially all of the provisions for each major area of product assurance plus identifying their initial requirements, based on class C. Under the column entitled CLASS C REQUIREMENTS, the required provisions are validated by an X or by text entry. If it is required, but with a proviso, a word or two is used to describe the implementing restriction or the modifier. Finally, if there is no requirement, a series of dashes is indicated. Appendix B provides definitions for the specific entries in the column entitled Provisions.

6.2.1 Radiation Threat

One requirement - radiation threat resolution - is a major concern to the IMPS mission. Therefore, at this initial instrument stage, a general requirement of need for the instrument packages is identified using a format of essential background information, resolution parameters, and preliminary requirements/assessments.

<u>Threat Mechanism Background</u>:

The mission requirements specified for the subsatellite (circular orbit, altitude 370 km, inclination 90 plus or minus 16 degrees, duration 2-10 days, and launch date ca. Spring 87) contain environmental stress factors which drive five principal classes of threat mechanism for the instrument system.

TABLE 6-1 IMPS Instrument Classification

PROVISION	CLASS C REQUIREMENTS
RELIABILITY	
o RELIABILITY ASSURANCE PLAN	X
o RELIABILITY ANALYSES	
– FMECA	ASSEMBLY LEVEL
– REDUNDANCY SWITCH	---
– ELECTRICAL PART STRESS	X
– STRUCTURAL/THERMAL STRESS	X
– MECHANICAL FAULT TREES	---
– WCA – CIRCUIT LEVEL	SUBSTITUTE ACCEPTABLE
– WCA – POWER SUPPLY TRANSIENT	X
– *FORMALLY DOCUMENTED*	PROJECT VARIABLE
– INDEPENDENTLY REVIEWED	PROJECT VARIABLE
o SINGLE FAILURE POINTS POLICY	PERMITTED
o REVIEW	
– REVIEW PLAN	X
REQUIREMENTS REVIEW	X
SYSTEM PDR	X
SYSTEM CDR	X
PRESHIP	X
PRE-LAUNCH	X
FR	---
IMPLEMENTATION	---
CERTIFICATION REVIEW	---

TABLE 6-1 IMPS Instrument Classification (Cont'd)

PROVISION	CLASS C REQUIREMENTS
RELIABILITY (Cont'd)	
SUBSYSTEM PDR	---
SUBSYSTEM CDR	---
PROBLEM/FAILURE ACCOUNTABILITY	
o PFR SYSTEM	X
o PFR INITIATION	DEVELOPMENTAL PFRS UTILIZED FROM TIME OF FIRST POWER APPLICATION, FOR ELECTRONIC/ELECTRO-MECHANICAL ASSEMBLIES, UNTIL ASSEMBLY ACCEPTANCE TEST.
o CONTROLLED BY R&QA MANAGER	AT START OF ASSEMBLY ACCEPTANCE TEST, FOR MISSION CRITICAL PFRs.
o RED FLAG AT PRESHIP AND PRE-LAUNCH	X
o PROJECT CLOSURE	X
ELECTRONIC PARTS	
o PARTS PROGRAM PLAN	X
o QUALIFICATION	X
o SCREENING SPECS	MILITARY
o PARTS SERIALIZATION	---
o CLASSIFICATION	---
o EPCS	PARTS LIST
o FAILURE ANALYSIS	SELECTABLE

TABLE 6-1 IMPS Instrument Classification (Cont'd)

PROVISION	CLASS C REQUIREMENTS
ELECTRONIC PARTS SELECTION SOURCES	
o API	X
o ZPP2061-PPL	
- WHITE	X
- BLUE	X
o MIL-STD-975	
- GRADE 1	X
- GRADE 2	X
o MIL-M-38510	
- CLASS S	X
- CLASS B	X
o MIL-S-19500	
- JANS	X
- JANTXV	X
o MILITARY ER	X
(LIFE FAILURE RATES WORSE THAN LEVEL R ARE NOT PERMITTED EXCEPT FOR CLASS D MISSIONS)	
o COMMERCIAL	---
ELECTRONIC PARTS TRACEABILITY	
o SERIALIZATION	---
o EPCS	N/A (PARTS LIST ONLY)
o CLASSIFICATION	---

TABLE 6-1 IMPS Instrument Classification (Cont'd)

PROVISION	CLASS C REQUIREMENTS
<u>MATERIALS AND PROCESSES</u>	
o JPL STD 00009	X
o DM 509306	X
o DIL	
- M LIST	---
- P LIST	---
<u>ENVIRONMENTAL PROGRAM</u>	
o DOCUMENTS	
- EPPRD (ENV. PROG. POLICY & REQUIREMENTS DOC.)	X
- ENVIRONMENTAL DESIGN REQUIREMENTS FR	---
- ENVIRONMENTAL REQUIREMENTS DOCUMENT	X
- CONTROL REQUIREMENTS DOCUMENT	---
- TEST/ANALYSIS CONFIGURATION DOC.	---
- GEN. ASSEMBLY/SYSTEM TEST SPEC.	---
- TRSF	X
- DETAIL TEST SPEC/ETSS	---
- DETAIL TEST SPEC/TESTS	X
- TEST PROCEDURE	X
- TEST AUTHORIZATION FORM	---
- ENVIRONMENTAL SAFETY REQUIREMENTS/ ASSESSMENT	---

TABLE 6-1 IMPS Instrument Classification (Cont'd)

PROVISION	CLASS C REQUIREMENTS
ENVIRONMENTAL PROGRAM (cont'd)	
o DESIGN REQUIREMENTS	
- VIBRATION - QUAL. LEVELS	X
- TEMPERATURE - QUAL. +/-10 C	---
- TEMPERATURE - QUAL.	X
- EMI - QUAL. LEVELS	---
- EMC - QUAL. LEVELS	X
- RAD-RDM 2	---
- RAD-RDM 1	X
- METEOROIDS	(AS REQUIRED BY SAFETY)
- ESD - 10 V	---
- MAGN-f (SCI)	---
- PRESSURE PROFILE - QUAL. LEVELS	X
- SAFETY (ONLY) (STS REQUIREMENTS)	---
SUBSYSTEM/ASSEMBLY ENVIRONMENTAL PROTOFLIGHT TEST REQUIREMENTS (SPECIFIC ENVIRONMENTS WILL BE DICTATED BY THE MISSION PROFILE.)	
o SINE VIBRATION	---
- AMPLITUDE/SWEEP RATE	
o ACOUSTICS (SELECTED)	---
- AMPLITUDE/DURATION	
o RANDOM VIBRATION (ACOUSTICS MAY BE MORE APPROPRIATE THAN RANDOM VIBRATION, DEPENDING ON SURFACE AREA TO MASS RELATIONSHIP.)	2.5 TIMES ACCEPTABLE PSD LEVELS; 1.0 TIMES ACCEPTABLE LEVELS

TABLE 6-1 IMPS Instrument Classification (Cont'd)

PROVISION	CLASS C REQUIREMENTS
- AMPLITUDE/DURATION	
o PYRO SHOCK (SELECTED)	---
o TEMPERATURE/AMPLITUDE	75°C & -20°C UNLESS EXCEEDED BY ALLOWABLE FLIGHT $\pm$ 25°C
o T/V DURATION	100 HOURS
o PRESSURE PROFILE	ß 1.5 P MAX
o EMC SUSCEPTIBILITY	
- CONDUCTED a) POWER BUS, b) SIGNAL LINES,	 a) YES b) NO
- RADIATED	NO
o EMC EMISSIONS	
- CONDUCTED a) POWER BUS, b) SIGNAL LINES,	 a) YES b) NO
- RADIATED	YES
o MAGNETIC FIELDS	NO
o EMC ISOLATION	YES
o ESD	
- EXTERIOR	NO
- INTERIOR	NO

TABLE 6-1 IMPS Instrument Classification (Cont'd)

PROVISION	CLASS C REQUIREMENTS
QUALITY ASSURANCE	
o QA PLAN	INSPECTION PLAN
o QA REP AT MAJOR SUPPLIERS (DCAS/AFPRO)	---
o WORKMANSHIP INSPECTION	ASSEMBLY LEVEL ONLY
o CONFIGURATION VERIFICATON	---
o TEST WITNESS	ENV
o HRCR	X
o AUDITS	---
o DOCUMENT REVIEW	X
o MRBs	X
o AIDS	---
o END ITEM DATA PACKAGE VERIFICATION	---
o SHIPPING	X
o PFR SURVEILLANCE	X
SOFTWARE IV AND V	
o VERIFICATION	
- SOFTWARE MANAGEMENT PLAN	---
- SYSTEM OBJECTIVE	---
- SYSTEM REQUIREMENTS	---
- INTERFACE REQUIREMENTS	---
- TEST PLAN	---

TABLE 6-1 IMPS Instrument Classification (Cont'd)

PROVISION	CLASS C REQUIREMENTS
SOFTWARE IV AND V (cont'd)	
- SOFTWARE REQUIREMENTS	ANALYZE TRACE REQUIREMENT, START TEST CASE GENERATION
- SOFTWARE DESIGN	TRACE REQUIREMENT
- SOFTWARE DESCRIPTION	AUDIT
- USERS GUIDE	---
- COMPUTER PROGRAM	AUDIT
o VALIDATION	
- COMPUTER PROGRAM	---
- COMPUTER OUTPUT	OUTPUT VALIDATION

These threat mechanism classes are:

(1) Total ionizing dose (TID) mechanisms
(2) Single event upset (SEU) mechanisms
(3) Electrostatic discharge (ESD) mechanisms
(4) Radiation induced current (RIC) mechanisms, and
(5) Plasma erosion mechanisms.

In addition, the IMPS instrumentation includes the deliberate stimulation of discharges and breakdown in dielectric specimens, simulating ESD mechanisms. This means that IMPS instrumentation will be subjected to electromagnetic pulses generated by these experiments which will certainly be more frequent, and may also be significantly larger, compared with naturally occurring pulses. In support of the IMPS instruments, it may be necessary to perform radiation survivability analysis as well as radiation hardness assurance efforts at the instrument level, which will address each of the five threat mechanism classes with special emphasis on complications arising from the dielectric discharge experiment.

6.2.2 Total Ionizing Dose (TID) Threats

In the IMPS case, TID mechanisms will be initiated primarily by charged particles channelled into the auroral zones by the earth's magnetic field. Additional particle contributions may be made by protons from an anomalously large solar flare, but these are unlikely events, and it is possible that the occurence of such an event may cause a mission abort, in order to protect the STS crew.

TID threats appear, more or less gradually, as long-lived changes in certain performance parameters (e.g. threshold voltage or tensile strength) become evident as radiation exposure increases. In most cases the parameter degrades monotonically with each increasing dose, usually in a non-linear fashion. In some cases, more complex behavior can be found (such as increase followed by decrease), but the overall result, especially for large doses, is degradation of the performance parameter. Post-irradiation changes - - ,

which sometimes further degrade the parameter and, at other times, causing it to recover - - have been observed in particular cases. Quite often, the radiation-induced degradation is so large that the affected component no longer can perform its function, i.e. catastrophic failure results.

Analysis of TID threats to any spacecraft instrument requires the following three main types of input information:

1) A description of the TID environmental stress factors as they exist in the absence of the instrument;

2) A description of the instrument configuration, including shielding materials;

3) A description of the electronic components contained in the instrument, including specifically, their TID capabilities and their locations within the spacecraft and shield.

At present, only an approximate description of the TID environmental stress factors, appropriate to the IMPS mission, is available. Estimated uncertainty factors have been applied to the available environmental data for a circular orbit of 370 km altitude, 90 degrees inclination, and ten days duration. The resulting TID values have been plotted against the shielding thickness. The resulting curve, presented as Figure 6-1, provides a conservative design guide for selecting electronic components hardened against TID damage mechanisms.

A design guide normally is used in the following way:

1) Estimate the approximate thickness of spacecraft material surrounding the proposed location of the instrument.

2) Using the design guide, the corresponding TID expected in the particular location is determined and then multiplied by the TID design margin factor (as previously established by the project radiation requirements document), in order to

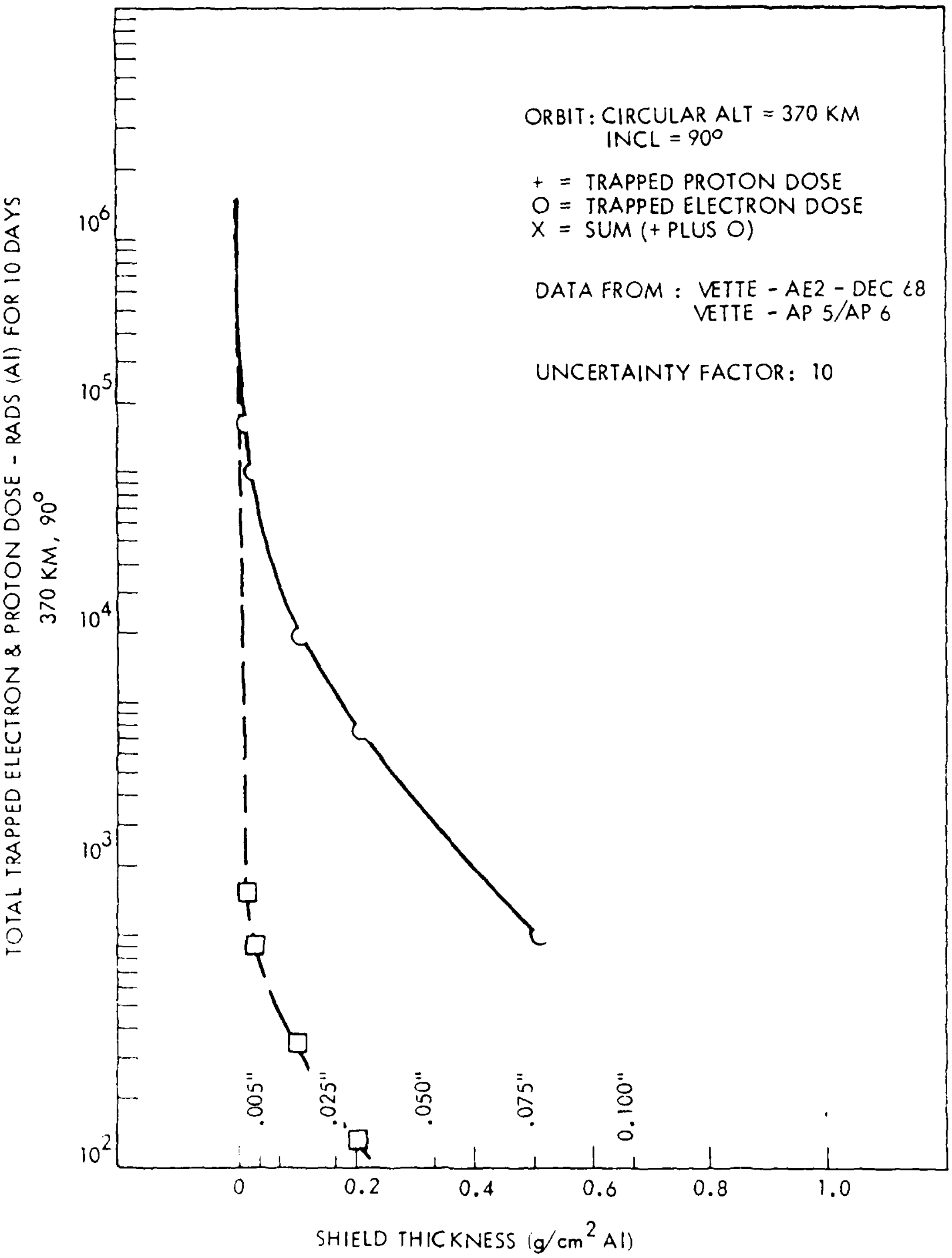


Figure 6-1. Total Ionizing Dose (TID) Design Guide for IMPS

find the required TID capacity for any component to be located at a specific site.

3) Establish the TID capacity applicable to the proposed instrument component and compare it to the required value determined above.

It should be noted that design guides are intended for use with components located inside the instrument, and are not suitable for evaluating and selecting materials located on the surface, such as paints or thermal blankets. Specifically, no attempt should be made to use the data in Figure 6-1 for shielding material thicknesses equivalent to less than .01 g/cm^2 of aluminum.

Finally, a caution is warranted that design guides apply only to threat mechanisms of the TID class. Hardening against radiation-related threats of other classes (e.g., single event upsets, radiation induced currents, displacement effects, et al) require other analyses and countermeasures appropriate to those threats.

It should be apparent from the above remarks that more information is required in order to perform the TID portion of a survivability analysis and hardness assurance effort. First, instrument construction and configuration details must be determined, including the disposition of mass and the locations of the various radiation-sensitive components. Second, the TID capabilities of the various sensitive instrument components must be likewise determined. And finally, a more accurate and detailed calculation of the internal TID environment should be made.

The radiation doses expected for the IMPS instrumentation are in the low to moderate range. Many electronic components are capable of operation after receiving TID's in the megarad region. Thus the probability of being able to assure a satisfactory IMPS given adequate controls on circuit design and component quality, is quite high. However, commercial quality

components have been known to go out of specifications after being subjected to TID's as low as 50 rads. Hence, assurance of satisfactory performance will require adequate TID capability controls on the components.

6.2.3 Radiation Induced Current (RIC) Threats

RIC threats usually are interference effects. For example, in one common case, the current in a transistor will increase during irradiation, due to additional ionization caused in the transistor by the radiation. If the radiation intensity is high enough, the transistor will saturate. Also, if the radiation intensity is high enough, all the transistor switches in the system may turn "on" simultaneously. The consequences here will depend to some extent upon the design of the circuit. However, the usual result is a temporary malfunction of the circuit which disappears more or less immediately once the irradiation stops. In one special case called latchup, a four-layer structure was excited into a permanent "on" state until the current was interrupted externally. If the interruption occurs because some component melts or burns out, this result becomes a catastrophic failure. For low intensity radiation fields, the usual result is the increase in background noise. Circuits intended to count photons or measure some other form of radiation energy are the most susceptible to this kind of interference.

As far as most instrumentation components are concerned, the ionizing radiation intensities encountered in the IMPS orbit are fairly low. Thus, unless the IMPS includes instruments that are especially sensitive to RIC effects (e.g. radiation detectors using Geiger tubes, or cameras using CCD components), the influence of RIC effects will probably be negligible. However, an RIC analysis of the instrumentation is necessary in order to assure that negligible amount of radiation has occurred. Analysis of RIC threats also requires three types of input information: a description of the environmental ionizing radiation stress factors, specifically including the intensity; a description of the instrument configuration, including shield; and a description of the electronic circuitry which specifies its RIC responses as functions of the local ionizing radiation dose rate. None of this information is immediately available, although a modest investigative effort

probably could discover most of it. Consequently, it is not possible at this time to reach any final conclusions regarding the thickness of shielding required to limit RIC effects in the IMPS.

Roughly comparable data on maximum radiation intensities have been calculated for other polar orbits. Similar calculations for the IMPS instrumentation will require only a modest effort, although the uncertainty factor of necessity will be rather large, and determining a "realistic" worst case dose rate would to a substantial degree be arbitrary. The data from calculations of other polar orbits probably will be just about as accurate as that derived from a special calculation for the IMPS orbit, and certainly will be adequate for the preliminary subsatellite design considerations.

6.2.4 Single Event Upset Threats

Single event upsets (SEU) are an example of so-called "soft" errors. An SEU occurs when an ionizing particle releases enough electrical charge in a sensitive volume of a device to cause the associated bi-stable circuit element to change from its pre-event state to the opposite state (i.e. either from a 0 to a 1 or vice versa), without doing any permanent damage to that element. Such a bit-flip is erased when the system next writes information into that element, and the element performs its subsequent functions as if the error had never occurred. Normally, this type of error is detected and corrected by other circuitry, or it appears as a small amount of noise in a signal and no harm is done. In critical cases, however, the result can be serious. For example, if the bit were part of an attitude control system, the error might cause the system to lose its ground communications linkage permanently, through mis-orientation of the communications antenna. While this particular problem poses no concern for the IMPS, the IMPS requirement for free-flight operation may imply vulnerability to SEU-caused shut-down and loss of data.

In the IMPS case, SEU mechanisms will be initiated primarily by galactic cosmic rays, especially during those portions of the orbit which lie

over the magnetic polar regions. The threat of proton initiated SEU's also exists, mostly during the times when the IMPS is in transition into or out of the polar regions.

SEU Hardness Assurance:

Assuring hardness against SEU threats, as in the case of TID threats, usually requires coordinated effort from two experts: one acquainted with SEU environments and mechanism, and capable of determining the SEU frequencies for given devices; the other acquainted with the instrument circuit designs, and capable of determining the effects of such upsets upon the subsystem's performance. If a given frequency of SEU's is found intolerable, it usually is necessary to alter the circuit, either by replacing SEU-sensitive devices with those having less sensitivity, or by modifying the circuit to a more upset-tolerant design.

6.2.5 Electrostatic Discharge (ESD) Threats

ESD threats arise because dielectric materials are capable of trapping electrical charge carriers, and keeping them trapped in fixed positions for long periods of time. This property can be quite useful, as in the case of electret microphones, for example. On the other hand, continued exposure of dielectric materials to high energy radiation can produce a localized build-up of electric fields in such components as thermal blankets or electrical insulation due to the presence of displaced or extraneous charge carriers.

The fundamental upper limit for the magnitude of such fields is imposed by the maximum energy of the incident particles, which frequently is some number of MeV, the fluence-rate of these particles, and the radiation-induced conductivity of the dielectric. For the proper combination of these parameters, the resulting local electric fields can exceed the material's dielectric strength, and cause catastrophic surface and/or volume breakdown. The situation frequently is worsened by the presence of included or near-by,

ungrounded metals, which can both increase the rate of displaced charge carrier generation and distort the local electric fields.

It should be noted that a partiular orbit is chosen in part to aid experiments evaluating spacecraft ESD mechanisms, so that the environment will be highly conducive to ESD events. This means that special attention must be paid to reducing the likelihood of extraneous ESD events occurring elsewhere other than in the ESD tests.

ESD Threat Analysis and Hardening Assurance

A standard practice for ESD threat analysis has not yet been adopted by the spacecraft community. Rules of thumb, setting upper limits on the unirradiated volume conductivity of dielectric materials are being developed but have not yet been refined to a science, and have not yet gained widespread acceptance. One of the purposes of the IMPS is to gain more information in this field in pursuit of establishing a basis for such standard practices.

A thorough analysis of ESD threats requires input information of two classes. First, a description of the appropriate environmental stress factors (in this case the plasma and the high-energy radiation environments). Second, a description of the electrical configuration of the instrument and its contents, with particular attention to the dielectric materials, their electrical parameters (especially their radiation-induced conductivities), their geometric relationships to the nearest metallic components, and the electrical connectivities of these metal components with each other and with spacecraft ground.

At this writing, much of the sought information is not readily available. Its acquisition remains for the follow-on effort, along with development of a set of standard practices for hardening against ESD threats.

6.2.6 Surface Erision Threats

This class of threat mechanisms is a catch-all for a number of chemical and electro-chemical processes arising from interactions between spacecraft materials and low-energy charged and neutral particles present in the orbital environment.

At present, these interactions are not significantly well-known for a standard practice for threat analysis and hardness assurance to have emerged. However, as in the case of ESD threats, the IMPS instrumentation is being designed to facilitate further investigation of this class of threats. Consequently, it is anticipated that the orbital environment will feature high levels of the corresponding environmental stress factors. These stress factors are caused by influences of relatively low-energy particles, such as neutral oxygen. As a result, only spacecraft components having surfaces exposed to the external environment are at risk from this class of threats. Therefore, a threat analysis will require two types of input information. First, a description of the environmental stress factors. Second, a description of the instrument's surface materials, including their properties that were relevant to the identified threat mechanisms.

6.2.7 Conclusions

The radiation environment associated with the IMPS orbit includes stress factors important in driving five separate classes of threat mechanism. These threat mechanism classes are

1) Total Ionizing Dose (TID) mechanisms
2) Single Event Upset (SEU) mechanisms
3) Electrostatic Discharge (ESD) mechanisms
4) Radiation Induced Current (RID) mechanisms
5) Surface erosion mechanism.

In addition, the IMPS mission includes the deliberate stimulation of discharges and breakdowns in dielectric specimens in order to, simulate ESD mechanisms. To assure that IMPS instrumentation will operate satisfactorily throughout specified missions, it will be necessary to perform a radiation survivability analysis and radiation hardness assurance effort which address each of the five threat mechanism classes mentioned above, with special emphasis on complications arising from the dielectric discharge experiments.

The information available at present on the subject of threat mechanisms is sufficient to permit an accurate estimate of the effort that will be required to perform the needed radiation hardness threat analysis and hardness assurance tasks for the IMPS instrumentation. However, pursuit of these undertakings will be more cost-efficient if the environmental stress factor definition tasks are performed for the IMPS project as a whole, rather than for each subsystem separately. Furthermore, the necessity for all instrumentation analyses to take into consideration the electromagnetic energy to be broadcast by the ESD experiments provides additional argument favoring a system, rather than a partitioned, approach. Consequently, a coordinated approach to these tasks is recommended. The size of the effort required should be determined as project design phases progress.

SECTION 7

RECOMMENDATIONS

7.1 ENGINEERING/SCIENCE

7.1.1 Environmental Modeling

Based on the results of the JPL modeling efforts, it is clear that several improvements must be made in current environmental models for IMPS. First, the IRI ionospheric model needs to be revised and streamlined for operation at Shuttle altitudes. This will probably mean only 0+ and H+ ions above 200 km will need to be considered. Moreover, the IRI model is tied to the Jacchia density model, whereas more modern studies use the MSIS model. Likewise, the IRI model uses the R number instead of the more correct flux value to account for solar activity. These and other minor discrepancies need to be corrected before the model can serve its purpose.

An adequate auroral model needs to be developed. To be of value to the IMPS, this model may need to make use of real-time measurements, such as those from the Defense Meteorological Satellite Project (DMSP). Again, further study is recommended in this area.

In the neutral atmosphere area, a streamlined version of the MSIS (or Jacchia) neutral density model needs to be developed for IMPS. A model (perhaps derived from the Rice magnetosphere model and one of the CRAY ionosphere/atmosphere models currently popular) of the real-time effects of an aurora on the density and composition of the neutral atmosphere will have to be generated.

In the area of interaction modeling, the AFGL POLAR code is still being developed to estimate charging and wake effects for the Shuttle. This model needs to be studied in the context of the IMPS; the outputs must be tailored to the IMPS mission. Radiation and cosmic ray models will need to be updated as soon as data from the Combined Release and Radiation Effects

Satellite (CRRES) become available. Surface erosion and glow models will be necessary to predict surface property changes. In conjunction with all these studies, an adequate contamination model will have to be developed as well. Currently, no model exists that can accurately predict what arc discharges will look like on the IMPS. The IMPS will have to be characterized electrically in great detail if ESD studies are to have any meaning.

7.1.2 Ground Test Plan

As discussed previously, perhaps one of the most valuable sources of data from the IMPS program will be the ground test efforts. If the data from IMPS are well understood and integrated into the overall interactions data base, then a carefully thought out and conducted ground program is a prerequisite. A pre-flight experimental effort (as opposed to integration testing) is necessary to characterize the expected responses of the instruments in the flight configuration, characterize the surfaces and systems before flight for comparison with post-flight results, and the development of synergistic experiments. Post-flight testing of the entire IMPS system will be necessary to verify postulated event configurations, to characterize the effects of the environment on surfaces and systems, as well as to provide a data base for follow-on flights of system performance degradation. As many of the instruments are flight adaptations of laboratory configurations, IMPS will ultimately allow confirmation of ground test technology. Since it is likely to be decades before in-flight testing of new systems without ground simulation is economically feasible, the verification and improvement of ground test technology is the area where IMPS will have the greatest impact on spacecraft design. For this and other reasons, it is strongly urged that careful forethought and planning be dictated into the ground test program. As most of the benefits are to be realized from synergistic studies between the instruments when mounted on the carrier, it is recommended that this be considered as a project function rather than one on an individual instrument level.

7.2 MISSION DESIGN

It is recommended that the launch period be in winter in the northern hemisphere because winter allows for the greatest period of darkness over the polar auroral zones. Darkness is desirable, since it is the best condition in which ground-based stations are able to observe auroral events. The northern hemisphere is preferable to the southern, since it is there where the majority of ground-based stations are located.

SECTION 8

CONCLUSIONS

The definition phase has seen the distillation of engineering/science objectives to a complement of instruments for the first IMPS flight and a preliminary set of objectives for follow-on flights. Working in concert with the engineering/science team, a system design team has determined the feasability of flying these missions on existing and future carrier systems. As a backdrop to the above tasks, a programmatic framework has been put in place that will allow a smooth transition from phase I, definition, to phase II, implementation.

The project, early in the definition phase, has developed the objectives and requirements presented in this report. The objectives are based on meeting the broad spectrum of instruments that will become part of the multimission IMPS and also in recognizing the unique nature of the Shuttle. This led to the cornerstone of the IMPS project which is adaptability towards the IMPS instruments and the Shuttle. For the implementation phase a similar set of objectives will be established with particular regard to flying very low cost missions.

The engineering/science team has worked in a logical fashion toward the following objectives: developing mission objectives from discussions with future AF large platform users; forming a board of experts in the field of environmental interactions with large space systems to identify investigations needed to meet their objectives; and finally, working with selected AF facilities to define the instruments to accomplish these investigations. In support of AFGL and these objectives, models of the Auroral and Polar environments were either developed or refined. The engineering/science team is now positioned to proceed on undertaking activities: first, to develop a clear and concise IMPS-1 mission plan, and second, to continue the definition of investigations to be conducted on future flights of the IMPS.

Instrument activities have focused on definition of requirements. The preliminary assessment has concluded that a set of instruments could meet a Spring 1987 launch. Many of these instruments are now positioned for start of phase II, implementations.

System design support to the IMPS payload study has developed a candidate carrier system that, by its nature, could support a number of IMPS missions without modification. As the IMPS-1 engineering/science has matured and low up-front cost become critical, the feasibility of using an existing carrier without modificaticn, will be investigated. It has also been determined that many of the earlier objectives of the project can still be achieved by the incorporation of an existing data bus, the Mil-Std 1553B.

In conclusion, the scientific and technical framework is in place to fly a low cost IMPS-1 in the Spring of 1987, representing exceptional growth potential for subsequent AGFL missions.

BIBLIOGRAPHY

<u>Flight Procedures Handbook</u>, Rendezvous, Mission Operations Directorate Operations Division, Preliminary, November 7, 1983.

<u>Flight Procedures Handbook</u>, Proximity Operations, Flight Operations Directorate Training Division, Preliminary, November 11, 1982.

<u>STS Interface Control Document, Level II</u>, Lyndon B. Johnson Space Center, Houston, January 28, 1981.

APPENDIX A

CONTENTS PAGES

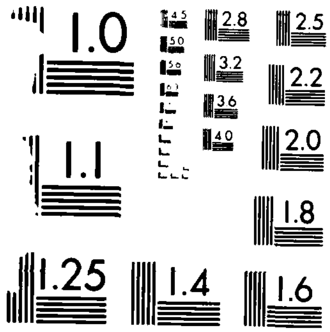
EXPERIMENT INTERFACE CONTROL DOCUMENT (EICD)

CONTENTS (Cont'd)

CONTENTS (Cont'd)

CONTENTS (Cont'd)

AD-A165 222 INTERACTIONS MEASUREMENT PAYLOAD FOR SHUTTLE (IMPS) 3/3
DEFINITION PHASE STUDY(U) JET PROPULSION LAB PASADENA
CA G C HILL 15 DEC 84 JPL-D-1865 AFGL-TR-85-0023
UNCLASSIFIED NAS7-918 F/G 22/2 NL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CONTENTS (Cont'd)

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APPENDIX B

ACRONYMS GLOSSARY

AC	Alternating Current or Attitude Control
AC/DC	Alternating Current/Direct Current
A/D	Analog-to-Digital
AF	Air Force
AFD	Aft Flight Deck
AFGL	Air Force Geophysics Laboratory
AFSTC	Air Force Space Test Center
AFWAL	Air Force Wright Aeronautical Laboratories
AFWL	Air Force Weapons Laboratory
AH	Amp-Hour
AIAA	American Institute of Aeronautics and Astronautics
APL	Applied Physics Laboratory
BPC	Bridge Payload Carrier
CCB	Change Control Board
CDR	Critical Design Review
CRRES	Combined Release and Radiation Effects Satellite
DC	Direct Current
DHS	Data Handling Subsystem
DME	Dielectric Charging, Material Property Degradation, and Electrostatic Discharge
DMSP	Defense Meteorological Satellite Project
DOS	Dosimeter
ESICD	Engineering/Science Interface Control Document
EIM	Environment and Interaction Monitoring

EMC	Electromagnetic Compatability
EMI	Electromagnetic Interference
EMT	Elapsed Mission Time
ENV	Environmental
EPCS	Electronic Parts Stress Analysis
ER	Established Reliability
E/S	Engineering/Science
ESD	Electrostatic Discharge
E/SWG	Engineering/Science Working Group
ETSS	
EVA	Extra Vehicular Activity
FIFO	First-In-First-Out
FMECA	Failure Modes, Effects and Criticality Analysis
FR	Functional Review
GPC	General Purpose Computer
IEEE	Institute of Electrical and Electronics Engineers
IBM PC	International Business Machines Personal Computer
ICD	Interface Control Document
IEU	Instrument Engineering Unit
IMPS	Interactions Measurement Payload for Shuttle
IOM	Inter-Office Memo
IR	Infrared
IRD	Instrument Requirements Document
IRI	International Reference Ionosphere
JANS	Joint Army/Navy Specification

JPL	Jet Propulsion Laboratory
JSC	Johnson Space Center
KSC	Kennedy Space Center
LDEF	Long Duration Exposure Facility
LET	Linear Energy Transfer
LIDAR	Laser Detection and Ranging System
LVLH	Local-Vertical Local-Horizontal
MAG	Magnetometer
MOA	Memorandum of Agreement
MODUS	Modular Digital Universal System
MIL-STD	Military Standard
MLI	Multilayer Insulation
MRB	Materials Review Board
MS	Mass Spectrometer
MSSTP	Military Space System Technology Plan
NASA	National Aeronautics and Space Administration
PASP	Photovoltaic Array Space Power
PD	Payload Data Interleaver
PDR	Preliminary Design Review
PDU	Power Distribution Unit
PEO	Polar Earth Orbit
PF	Protoflight
PFR	Problem Failure Report
PI	Payload Interrogator or Principle Investigator
PIX	Plasma Interactions Experiment

PM	Phase Modulation
POCC	Payload Operations Control Center
PP	Plasma Probe
PSK	Phase Shift Keying
PSP	Payload Signal Processor
PSPIF	Payload Signal Processor Interface
PTC	Passive Thermal Control
R&QA	Reliability and Quality Assurance
RAM	Random Access Memory
RADC	Rome Air Development Center
RF	Radio Frequency
RIC	Radiation Induced Current
RMS	Remote Manipulator System
SBL	Space-Based Laser
SBR	Space-Based Radar
SD	Space Division
SEARCH	Search Coil Magnetometer
SEU	Single Event Upset
SIIO	Space Irradiated Integrated Optics
SIP	Standard Interface Panel
SMCH	Standard Mixed Cargo Harness
SPO	Special Project Office
SRB	Solid Rocket Booster
STC	Satellite Test Center
STDN	Spaceflight Tracking and Data Network

STP	Space Test Program
STS	Space Transportation System
TDM	Time Division Multiplexed
TDRS	Tracking and Data Relay Satellite
TDRSS	Tracking and Data Relay Satellite System
TID	Total Ionizing Dose
TQCM	Thermally-Controlled Quartz Crystal Microbalances
T/R	Tape Recorder
T/V	Thermal Vacuum
UV	Ultraviolet
VAFB	Vandenberg Air Force Base
VIB	Vibration
WCA	Worst Case Analysis

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